DRILLING
ND PRODUCTION

PIPE LINE

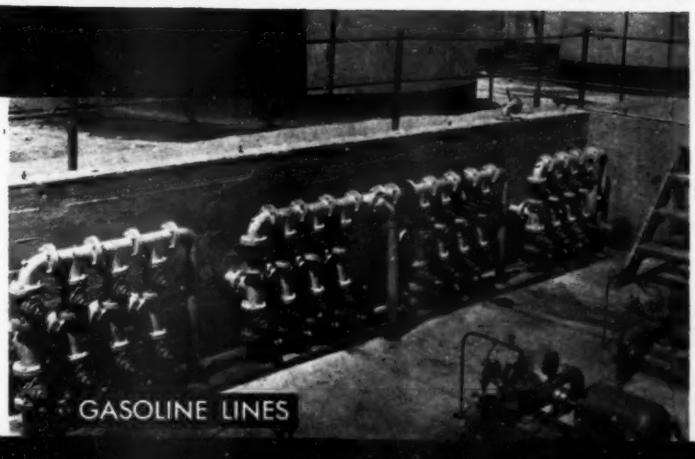
REFINING
NATURAL GASOLINE

LOADING LINES

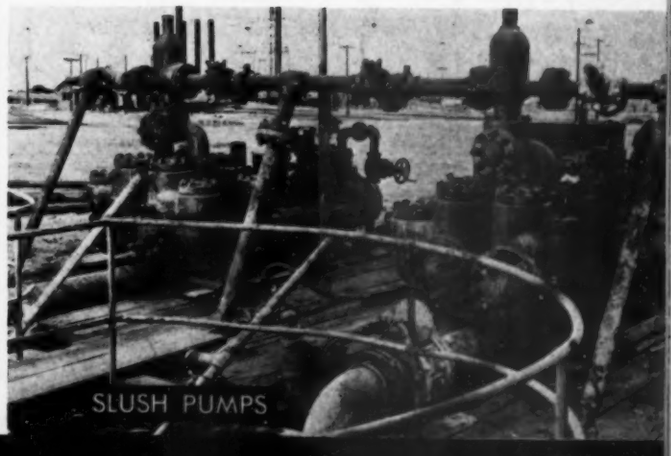
CHRISTMAS TREES

GAS TRANSMISSION

MUD LINES



GASOLINE LINES



SLUSH PUMPS

Signed, Sealed and Delivering the Goods!

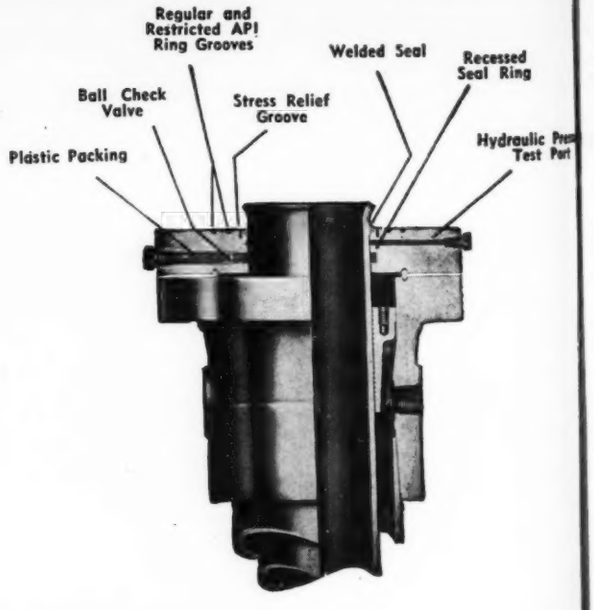
CAMERON

Type "M" Test-Weld Flange

CASING HEADS

Cameron Type "M" Test-Weld Flange Casing Heads have proven conspicuously successful in suspending and sealing casing in hundreds of deep, high-pressure Gulf Coast wells. Note in the cross-section drawing at right that the entire casing load is carried by the slips, the sole function of the welding flange being to provide a pre-tested pressure-tight seal between casing strings. After the welded seal is applied, plastic packing is injected thru a port in the flange to force a recessed moulded ring into sealing engagement with the pipe. This in itself provides an efficient seal between casing strings and may be safely tightened, or repacked, at any time without disturbing the well head assembly by simply injecting more plastic packing thru the check-valve port. Hydraulic test pressure is then applied thru a port provided for this purpose. Defects in either seal may then be detected and corrected before completion of the well.

See your Composite Catalog for complete details on all types of Cameron well heads, or literature will gladly be sent to interested operators on request.



CAMERON IRON WORKS OIL WELL SPECIALTIES

ASSOCIATION OF WELL HEAD EQUIPMENT MANUFACTURERS CERTIFIED

CAMERON IRON WORKS, INC.

711 MILBY ST., HOUSTON, TEXAS

Export: 74 Trinity Place, New York, N. Y. *California:* The Howard Supply Co., Los Angeles. *Rocky Mountain:* Mountain Sales & Service, Casper, Wyoming

● A wealth of "know how" and valuable new methods have been fried out by the heat of the most intense production period this organization has known since its first days in 1878. . . . To be sure, most of the valves we have made have gone directly to the war effort. But as soon as the materials pressure upon the Nation and the demand for this production from us ease up, you will find great gains reflected in the very valves we will be producing for you.

READING-PRATT & CADY

MANUFACTURERS OF
READING CAST STEEL VALVES AND FITTINGS
PRATT & CADY BRASS AND IRON VALVES
D'ESTE VALVE AND ENGINEERING SPECIALTIES

Reading, Pa., Atlanta, Boston, Chicago, Houston, Los Angeles, New York, Philadelphia, Pittsburgh, Portland, San Francisco

A DIVISION OF AMERICAN CHAIN & CABLE COMPANY, Inc., BRIDGEPORT • CONNECTICUT

January, 1944

THE Petroleum Engineer

VOL. XV NO.

THE PETROLEUM ENGINEER PUBLISHING CO. . . . Phone: Central-4571 . . . Seventh Floor Allen Building . . . DALLAS 1, TEXAS
Clarence Morris, President, 1929-40

A Magazine of Methods for Operating Men

EXECUTIVE

W. L. LOVE
President
W. T. BRYAN
General Manager and Treasurer

EDITORIAL

K. C. SCLATER
Vice-President and Editor
FRANK H. LOVE
Managing Editor
C. C. PRYOR
Associate Editor
ERNESTINE ADAMS
Assistant Editor
JOHN H. KUNKEL
Refinery Editor
52 Vanderbilt Avenue
New York 17, N. Y.
WALLACE A. SAWDON
Pacific Coast and Foreign Editor
2062 Paramount Drive
Los Angeles 28, California
Telephone: HIlside 1695

ADVERTISING

T. J. CROWLEY
Vice-Pres. and Advertising Mgr.

NEW YORK 17, N. Y.

ROGER MOTHERAL
52 Vanderbilt Avenue
Telephone: Murray Hill 4-1880

CHICAGO 6, ILL.

E. V. PERKINS
330 South Wells Street
Telephone: HARrison 1843

LOS ANGELES 36, CALIF.

R. C. WIPPERMAN
518 North Sweetzer
Telephone: Webster 9617

DALLAS 1, TEXAS

JOE B. WOODS
Allen Bldg.
Telephone: C-4571

CIRCULATION

C. R. BARRETT
Circulation Manager

CONTENTS

DRILLING AND PRODUCTION — *Page*

Drilling Program in California — 78
By WALLACE A. SAWDON

"Swamp Buggy" Made from Salvaged Materials — 82
By DON ATTAWAY

Dually Completed Oil and Gas Wells — 85
By L. L. JORDAN and ALEC CROWELL

Correlation of Polished Rod Acceleration and Well Load — 95
By KENNETH N. MILLS

Time As a Factor in Economics of Oil Field Exploitation — 116
By LESTER C. UREN

Cementing Casing Through Troublesome Zones — 152
By WALLACE A. SAWDON

Gamma Ray Logging in East Texas — 156
By JOHN L. P. CAMPBELL

Wellhead Pressure Reduced by Subsurface Regulation — 160
By JOHN O. FARMER

What It Costs to Drill — 181
By W. K. POWELL

Gravel Packing Wells — 192
By C. C. PRYOR

REFINING AND NATURAL GASOLINE MANUFACTURE

Recent Developments in Welded Refinery Equipment — 103
By RUSSELL J. LOVE

Modern Direct-Fired Tubular Oil Heater (Part 2. Concluded) — 130
By R. G. LOVELL

Motor Vehicles Propelled by Producer Gas (Part 2. Concluded) — 144
By GUSTAV EGLOFF and PRUDENCE VAN ARSDELL

OIL AND GAS TRANSPORTATION

Maintaining Compressors at Peak Operating Efficiency — 88
By B. C. THIEL

Pipe Line Reconditioned, Flow Reversed — 124
By FRANK H. LOVE

The "Big Inch" Pipe Line — 185
By WALLACE R. FINNEY and J. B. ADOUE

GENERAL

Domestic Oil Shortage—A Challenge to the Oil Industry — 63
By H. J. STRUTH

Making a Brake Test Properly — 90
By W. F. SCHAPHORST

Calculator Computes I^2R Loss in Wire Circuits — 100
By V. W. PALEN

Tanks and Containers for Gas — 122

Determining Size of Diesel Exhaust — 128

REGULAR FEATURES

	Page		Page
The Course of Oil	12	Laugh With Barney	196
Highlights in Oildom	14	Running Tour With Men in the Industry	198
Major Refining Activities	16	Machinery and Equipment	200 and 202
Major Pipe Line Activities	18	Book Reviews	215
Major Oil Field Activities	20	Trade Literature	216
Petroleum Statistics and Field Operations	23	Meetings	218
The Petroleum Engineer's Continuous Tables (Installment No. 79)	165		

MEMBER A.B.C.—A.B.P. (The articles in *The Petroleum Engineer* are indexed in the *Industrial Arts Index*, New York, N. Y.)

Copyright 1944, by The Petroleum Engineer Publishing Company

STATEMENT OF CONDITION

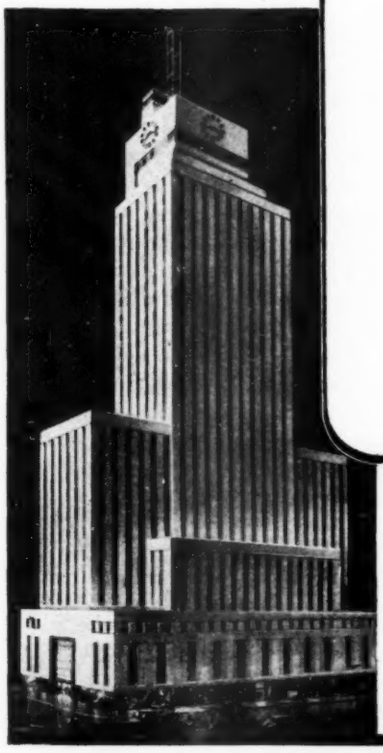
December 31, 1943

OUR RESOURCES

Cash and Due from Banks	$31,285,946.24	
U. S. Government Securities	39,591,903.11	$ 70,877,849.35
Stock in Federal Reserve Bank		150,000.00
Municipal and Industrial Bonds		2,183,616.74
Loans and Discounts		28,465,499.44
Vaults, Furniture and Fixtures		257,971.19
Bank Building		2,404,253.08
Other Assets		1.00
		$104,339,190.80

OUR LIABILITIES

Capital Stock		$ 2,500,000.00
Surplus		2,500,000.00
Undivided Profits		560,665.70
Reserve for Taxes, etc.		260,000.00
DEPOSITS:		
Individual	$58,303,195.87	
Banks and Bankers	31,975,371.45	
U. S. Government	8,239,957.78	
Total Deposits		98,518,525.10
		$104,339,190.80



Serving Oil Men of the Great Southwest with an understanding of their financial requirements.

MERCANTILE NATIONAL BANK

AT DALLAS • MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

The Course of Oil

by K. C. SCLATER

1944 WILDCATTING PROGRAM

There has been a serious depletion of the nation's available oil reserves during 1943. Military and civilian needs created a demand unprecedented in the history of the industry, and this year the demand will be even greater. This prospect of mounting oil demand in 1944 accentuates our dwindling oil reserves and the increasingly disappointing results obtained from wildcatting operations in the United States since 1939. The volume of new oil discovered last year was only about one-fourth of the total volume of oil produced. That is just how unfruitful wildcatting drilling efforts were in 1943, even though 119 more wildcat wells were drilled than in 1942. How to build up an ample reserve of oil to meet essential civilian and unpredictable war needs has therefore become the paramount problem confronting the producing branch of the industry in 1944. Whether the best effort the industry is permitted to put forth can accomplish this in time to prevent a crisis, remains to be seen.

Increasing the rate of production from existing wells, if this must be done, will only impair existing available oil reserves and add to the ultimate cost of production, for most of the wells are already producing at their optimum rate. An expansion of secondary recovery operations can augment the source of available oil, but probably not in sufficient quantity and time to be of the substantial aid necessary to meet the impending shortage. The dire immediate need is for new fields and more new wells.

As for new fields, these are becoming increasingly difficult to find. An adequate technique has yet to be developed for finding "stratigraphic traps" favorable to the accumulation of oil and gas. East Texas, the largest oil field yet discovered in the United States, is a field of the stratigraphic-trap type. It was discovered by an independent wildcatter. In the absence of some suitable means whereby stratigraphic traps can be located from the surface, fields of this type must be located by drilling, aided by an intensive study of the regional geology. Perhaps old-time random wildcatting, if resorted to, might turn the trick; but the cost of wildcatting is now high compared with what it was only a few years ago. At any rate, the element of chance is still a factor in oil prospecting, and that being so, the greater the number of wildcats drilled the greater will be the chances of discovery.

Safe working levels for available oil reserves should be at least fifteen and preferably twenty times as great as annual production. The present ratio of oil reserves is only eleven times as great as the annual production, a level much too low in view of the expected demand this year. At the close of 1943 there was an increase in wildcat drilling activity, which was largely the result of more critical materials being available and a relaxing of drilling restrictions. As Struth points out, however, the increase may stem from a buoyed-up hope that a crude price increase is in the offing.

As for new wells, the P.A.W. has announced that for 1944 the drilling program for which materials will be made available is 24,000 wells. Of these, 5000 will be wildcats and 19,000 development wells. That is a relatively high proportion of wildcat wells to development wells, but is it high enough? Even 5000 wildcat wells may fall far short of finding enough oil, unless, of course, another East Texas field is discovered or the degree of wildcatting success far exceeds that of the last five years. An analysis of exploration expenditure for 1943 indicates just how inadequate a program of 5000 wildcats could turn out to be. H. J. Struth, in an article in this issue, points out that expenditures for exploration in 1943 indicate that 10,500 wildcat wells would have to be drilled this year to meet the expected demand for 1,625,000,000 barrels of oil. This number of wells was arrived at by assuming that 155,000 barrels of oil would be discovered for each wildcat drilled, which is the average discovery rate for the last three years. Drilling 10,500 wells would entail an expenditure—assuming an average current cost of $54,000 a well—of 570 million dollars or about 200 million dollars more than was spent on wildcat wells last year. Getting down to unit costs, Struth's figures show that it cost 49.1 cents for each barrel of oil (exclusive of royalty oil) discovered in 1943, whereas the annual average cost in the years 1935 to 1939 was only 9.2 cents a barrel. In 1943 then, it cost more than five times as much to discover a barrel of oil as it did in the years 1935 to 1939.

These rapidly mounting costs deter many wildcatters from embarking on a vigorous drilling campaign such as is needed. Even though sufficient materials and manpower are made available for an expanded drilling program, lack of a general increase in the price of crude petroleum will still be a deterring factor in wildcatting. Unless a general price adjustment is forthcoming it is seriously doubted that the oil industry will be enabled to do the job it so earnestly wants to do to hasten victory.

NO GOVERNMENT PARTICIPATION

The Petroleum Industry War Council has just declared its opposition to the government's participation, either directly or indirectly, in ownership or operation of foreign oil properties. Further, it urges that the government establish without delay a foreign oil policy that will protect American enterprise abroad.

Oil being an indispensable sinew of war and an almost equally indispensable commodity of peace, it will be one national resource that will come up for serious consideration and settlement by the council of Allied Nations. Whatever the decisions made in regard to oil resources in the postwar world, it is to be hoped they will not depart too far from the recommendations of the Foreign Oil Operations Committee of P.A.W.

Dependable "PREformance

DEPENDABLE equipment is a means to efficient performance. This is one important "WHY" of America's magnificent production record. Our own high standards in every phase of wire rope manufacture over a period of many years, has made it possible for our product to shoulder a greater share of the extra burden imposed by war. Preformed "HERCULES" (Red-Strand) Wire Rope is especially qualified for the difficult jobs. The inherent qualities of this time-tested rope, plus the advantages of Preforming—make for easier, quicker and safer work . . . more production from each pound of steel . . . greater efficiency.

MADE ONLY BY

A. LESCHEN & SONS ROPE CO.

WIRE ROPE MAKERS — ESTABLISHED 1857

5909 KENNERLY AVENUE — ST. LOUIS, MISSOURI, U. S. A.

NEW YORK . . . 90 West Street
CHICAGO . . . 810 W. Washington Blvd.
DENVER . . . 1554 Wazee Street

SAN FRANCISCO . . . 520 Fourth Street
PORTLAND . . . 914 N. W. 14th Avenue
SEATTLE . . . 3410 First Avenue South

Highlights IN OILDOM

Sees Oil Shortage Ahead

William R. Boyd, Jr., president of the American Petroleum Institute and chairman of the Petroleum Industry War Council, sees a shortage of petroleum products for civilians after military needs have been filled. In a recent statement Boyd said:

"The production of crude oil has not received the same encouragement or incentive to expand as has the production of other vital commodities such as aluminum, magnesium, explosives, etc., and the result is that the United States will probably strain its productive capacity in 1944 and still be unable to produce enough oil to supply both our war machine and to reasonably satisfy civilian requirements.

"The facts are simple and should be clearly understood by everyone who cannot get the quantity or quality of gasoline or oil that he would like. A year ago we had only about 1,700,000 men overseas, but by next July that number will have trebled to more than 5,000,000. Trebling our overseas army obviously trebles the requirements for fighting oils. Can our oil production be trebled or even doubled? Not a chance.

"This situation means that during 1944 the primary cause of public inconvenience as regards oil will still be the war, but this year the secondary cause will be lack of crude petroleum which cannot be remedied as easily or as promptly or as cheaply as was the lack of transportation facilities in 1942, and the shortage of refining capacity in 1943. New oil fields simply cannot be found by the same procedure that builds pipe lines, tankers, and refineries.

"Part of the answer will be found by drawing on all possible foreign sources for some of our military requirements as well as for some of our civilian needs.

"Another part will be found in the drilling, of more than the 1943 total, of nearly 19,000 wells in known oil fields of this country and in the search for new fields. But it now appears that most of the answer, particularly on the West Coast, which is already importing oil from Texas, must be found in the reduction of both the quantity and quality of civilian gasoline.

"Don't forget that our average fighting man overseas requires his weight in oil every three days to get him there, keep him going and protect him overhead. And remember also that it takes an average of three tons of 100 octane gasoline to deliver and drop one ton of bombs. Think of that when you read of 2000 tons of bombs being dropped on German and Japanese objectives and hope that there will be an ever-increasing tempo of such savage blows until the enemy is crushed and you can once again drive into the gasoline station and say with confidence and certainty 'Fill 'er up.'"

Changes In Compensation Rates

Beginning January 1, 1944, payment of premiums on workmen's compensation, public liability, and employer's liability in Texas is based on straight-time wages and not on overtime or doubletime. As an example, premiums for a 56-hr., 7-day workweek, at $1.00 per hr., would be payable on $56 only, or on the basis used before the wage and hour law went into effect. This practice will mean a distinct saving on premiums paid by employers.

Other oil producing states that also permit payments to be made on this basis include Ohio, Michigan, Illinois, Oklahoma, New Mexico, Kansas, Arkansas, Louisiana, Indiana, Kentucky, Mississippi, Montana, Nebraska, West Virginia, and Wyoming.

Texas was one of the last states to permit elimination of overtime and doubletime provisions in the calculation of compensation insurance premiums, but in doing so brought uniformity of procedure to the various oil producing states.

Take Drilling Equipment Census

The aid of all drilling contractors is being asked by the Petroleum Administration for War in the survey it is conducting to determine estimated 1944 requirements for rotary drilling equipment. Drilling contractors who have rotary rigs in operation, or who have equipment stacked that they intend to place in operation during 1944, are being urged to fill out Form PAW-37 at once.

A. H. Rowan, president of the American Association of Oilwell Drilling Contractors, has received the following letter from Frank A. Watts, PAW director of materials, concerning the survey:

"We are particularly anxious that each rotary drilling contractor who has a rig in operation or who has a rig stacked that he expects to place in operation during 1944, be afforded an opportunity to fill out and supply the information covered by Form PAW-37.

"We are anxious to initiate whatever procedures and take whatever steps are necessary to provide a 1944 supply of drilling machinery. If all production operators and oil well drilling contractors who own and now operate, or who expect to operate drilling rigs during 1944, will conscientiously and to the best of their ability fill out Form PAW-37, we believe it will assist measurably in enabling us to provide a program to supply 1944 drilling machinery requirements."

PIWC Asks Definite Foreign Policy

The government's foreign oil policy was the subject of recommendations set forth by the Petroleum Industry War Council when it met to consider a report submitted by its committee on petroleum foreign reserves. The report strongly opposed, either directly or indirectly, the government's participation in ownership or operation of foreign oil property.

Four specific recommendations approved were:

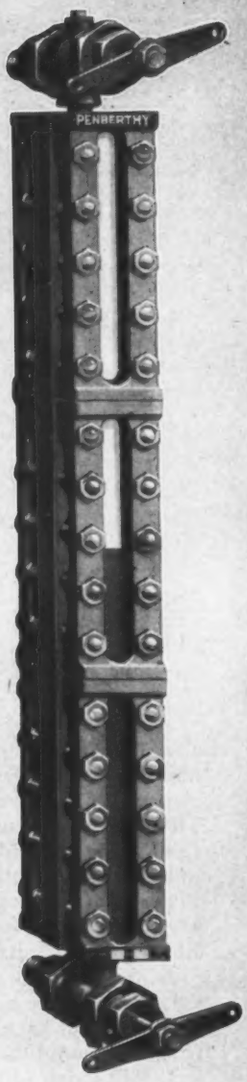
1. The oil resources of the world can best be developed by private enterprise under a free economy.
2. A foreign oil policy should be established at once by the United States.
3. This policy should involve strong support by our government to our nationals who are willing and able to play an important role in the development of the oil resources of the world.
4. The government should not participate directly or indirectly in the ownership or operation of foreign properties.

The council found that the report of the foreign operations committee that met with its approval "vigorously presents the advantages of private enterprise in foreign oil development, points to great achievements already made by American nationals in this field and gives convincing arguments to show that direct or indirect participation by the United States government in foreign oil development will hamper the diligent and efficient prosecution of such developments, will be a long step away from democratic precedure, and will lead to endless political and international complications."

A similar resolution was adopted recently by the board of directors of the Independent Petroleum Association of America, which called on the government to establish and maintain a consistent foreign oil policy based on provisions like those stated by PIWC.

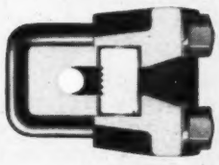
The resolutions resulted from the formation of Petroleum Reserves Corporation, a government agency with unlimited financial backing that was organized to develop foreign oil resources. Petroleum Administrator Ickes is president of PRC.

QUALITY UNCOMPROMISED



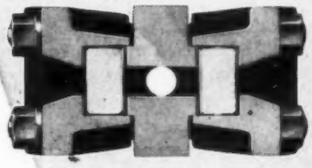
PENBERTHY
Reflex
DROP FORGED STEEL LIQUID LEVEL GAGES

Liquid shows black—empty space shows white. Preferred wherever liquid level must be easily and positively visible . . . and when liquids are under high pressure or at high temperature.



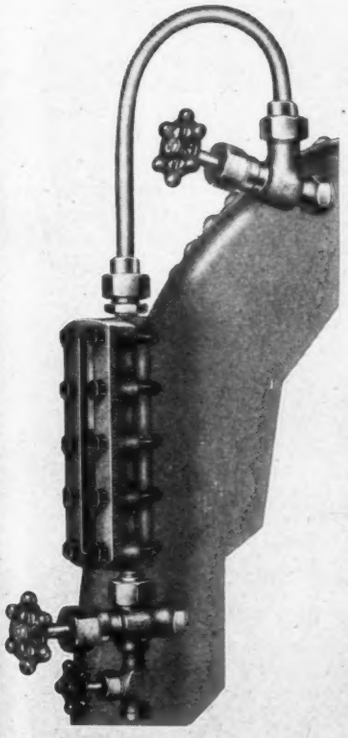
PENBERTHY
Transparent
DROP FORGED STEEL LIQUID LEVEL GAGES

Used to observe color and density of liquids under high pressures, and/or temperatures. Construction is exceptionally rugged . . . similar to Reflex types.



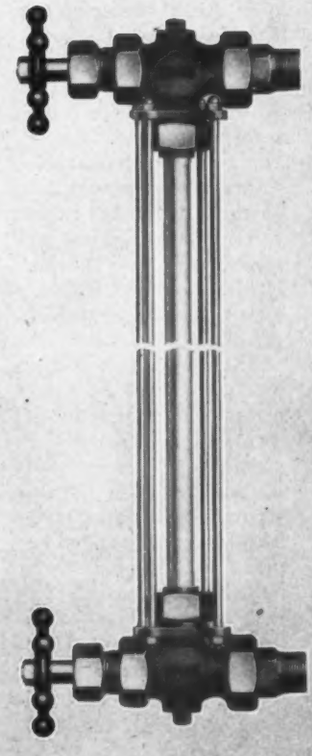
Penberthy Liquid Level Gages

ALL PENBERTHY GAGES
CONFORM WITH A. P. I.—A. S. M. E. REQUIREMENTS



PENBERTHY
Reflex
WATER GAGE SET

Water shows black—steam shows white. U-bolt construction is strongest and simplest to service. Glass replaced by simply removing nuts on face of gage . . . unnecessary to work between gage and boiler.



PENBERTHY
DROP FORGED STEEL LIQUID LEVEL GAGES

Made of Chromium-molybdenum alloy temperature-resisting steel, extra heavy throughout. Stainless steel trimmed. Tubular glass type gages also available in various other metals suitable for practically all conditions.

PENBERTHY INJECTOR CO.

DETROIT, MICHIGAN • Canadian Plant: Windsor, Ontario

PENBERTHY INDUSTRIES

MAJOR *Refining* ACTIVITIES

A SHIPMENT of oil refining machinery and equipment from the United States for Petroleos Mexicanos, the Mexican government oil administration, was recently reported by El Nacional, government periodical. Construction of a plant to make high octane gasoline is expected to begin soon on a site near Mexico City. The shipment, which is said to total $2,500,000 in value, will be paid for in large part by Mexican shipments of oil, the report states.

Petroleos Mexicanos, or Pemex, has been in dire need of more refining facilities. At the present time 100-octane gasoline is shipped from the United States when the Mexican potential daily production of more than 150,000 bbl. is much more than the existing demand both for domestic and foreign markets. Average daily production during 1943 averaged about 90,000 bbl. The new refinery, it is said, will be capable of producing 1500 bbl. daily of 100-octane gasoline.

Reports also have it that Pemex is scheduled to receive several oil tankers from the United States during the year, which would be an added stimulus to exports of oil from Mexico.

A group of independent oil refiners have agreed to present government officials with a plan designed to increase oil refining in the Midwest, which would have an idle refining capacity of 300,000 bbl. a day by next June, it was stated. The plan, announced by B. L. Majewski, vice president of Deep Rock Oil Corporation and chairman of the Petroleum Industries Marketing Committee for District 2, proposed:

1. Use of the Little Big-Inch pipe line from Texas to Norris City, Illinois, to carry into the district 100,000 bbl. of crude oil daily for 100 days.
2. Shipping 50,000 bbl. a day of West Texas crude oil into the district under an arrangement in which all refiners would be reimbursed by the government the difference between freight rates and the cost of moving the oil by pipe line.
3. Relaxation of government oil regulations to permit the drilling of new oil wells 10 acres apart instead of 40 acres.

Engineering for the 22 plants for 100-octane aviation gasoline in the 1944 construction program is already more than three-fourths complete, the Petroleum Administration for War announced.

As of December 1, in addition to the thousands of man-hours of work on contractors' structural blue prints, actual construction of these major 100-octane gasoline refineries was well under way, and the purchasing of building materials was more than 80 per cent completed.

"By this time next year, we expect these additional plants to be completed and increasing substantially the stream of aviation fuel flowing to the fighting fronts," said Administrator Harold L. Ickes. "Production from the plants to be built in 1944 will furnish the victory margin for the knockout blows of the United States and Allied air forces against the enemy.

"The volume of 100-octane gasoline has been increased many fold in the short space of two years. There are 163 plants, large and small, throughout the country, which are now contributing to its manufacture, and still we do not have all that we are going to need.

"Completion of the 22 major refineries scheduled for 1944 construction will conclude the vast 100-octane building program, initiated by PAW, in cooperation with the oil industry, in the spring of 1942, at the tremendous cost of $900,000,000. How much 100-octane gasoline actually is being used and will be needed to win the war cannot be revealed, but it is expected that, with the added production from these plants, the volume of fighting fuel will be raised to levels adequate to meet the war demands as they now are anticipated by Allied strategists."

It was announced last month that 11 more 100-octane aviation plants have been completed within the last 90 days and are now in production, adding thousands of barrels each day to the supply available for stepped-up offensives.

These plants, which have recently gone into operation, bring the total of completed major 100-octane projects to 34, and represent about $71,000,000 of the $900,000,000 building program.

Pure Oil Company has just completed one new alkylation plant and has a big thermofor catalytic cracking unit near completion. The first unit, owned by the Defense Plant Corporation and operated by Pure Oil Company, is producing large quantities of an important component for 100-octane gasoline. It is situated adjacent to the company's Smiths Bluff refinery at Nederland, in the Beaumont area of the Texas Gulf Coast.

Also in the same group is the cracking unit. It will supply butylenes to the Neches Butene Products Company, the world's largest butadiene plant in the synthetic rubber program.

High octane fuel will not be wanted or needed for postwar automotive engines, it was asserted by C. B. Veal of the Coordinating Research Council, Inc., of New York. High octane fuels produce tremendous combustion pressures and any automotive engine that could be developed to use them effectively would be too expensive, too heavy, and too noisy for the American motoring public, he stated.

The Coordinating Research Council is jointly sponsored by the American Petroleum Institute and the Society of Automotive Engineers.

The public, Veal predicted, would be interested in lighter, smaller engines, and he pointed out that production of high octane fuels consumes special chemicals at costs prohibitive in peacetime, and greatly reduces the yield of fuel per barrel of crude oil. Even should designers produce an engine capable of operation with high octane gasoline, the refiner would be forced to adopt uneconomic refining methods.

Crude Runs to Stills, Production[1] and Stocks[2] of Motor Fuels
Week Ended December 25, 1943
A.P.I. Figures
(Figures in thousands of bbl. 42 gal. each)

DISTRICT	DAILY REFINING CAPACITY Potential rate	DAILY REFINING CAPACITY Per cent reporting	CRUDE RUNS TO STILLS[3] Daily average	CRUDE RUNS TO STILLS[3] Per cent operated	PRODUCTIONS[3] Total production	PRODUCTIONS[3] Total stocks
*Combined: East Coast, Texas Gulf Louisiana Gulf, North Louisiana-Arkansas, and Inland Texas	2,444	88.7	2,111	86.4	13,866	79,293
Appalachian	177	171.1	144	181.4	8,140	4,583
Ind., Ill., Ky	824	85.2	741	89.9	4,644	25,687
Okla., Kans., Mo.	416	80.1	328	78.8	2,056	10,702
Rocky Mt.	149	85.2	108	206.3	627	2,550
California	817	89.9	753	92.2	5,185	62,723
TOTAL U. S.— Dec. 25, 1943	4,827	86.4	4,185	86.7	27,192	185,540
TOTAL U. S.— Dec. 18, 1943	4,827	86.4	4,146	85.9	26,301	185,593
U. S.— Dec. 26, 1942	.....	.....	3,508	.....	22,537	206,699

*At the request of the Petroleum Administration for War.
[1]Production—total of gasoline at refineries including natural and blended; kerosine, gas, and distillate fuel oil, and residual fuel oil.
[2]Stocks—at refineries, bulk terminals, in transit, and pipe lines of finished and unfinished gasoline; kerosine, gas, oil, and distillate fuel, and residual fuel oil.
[3]Figures on production and stock include reported totals plus an estimate of unreported amounts and are therefore on a Bureau of Mines basis.

FLUID CATALYTIC CRACKING

The ONLY process charging HEAVIEST stocks

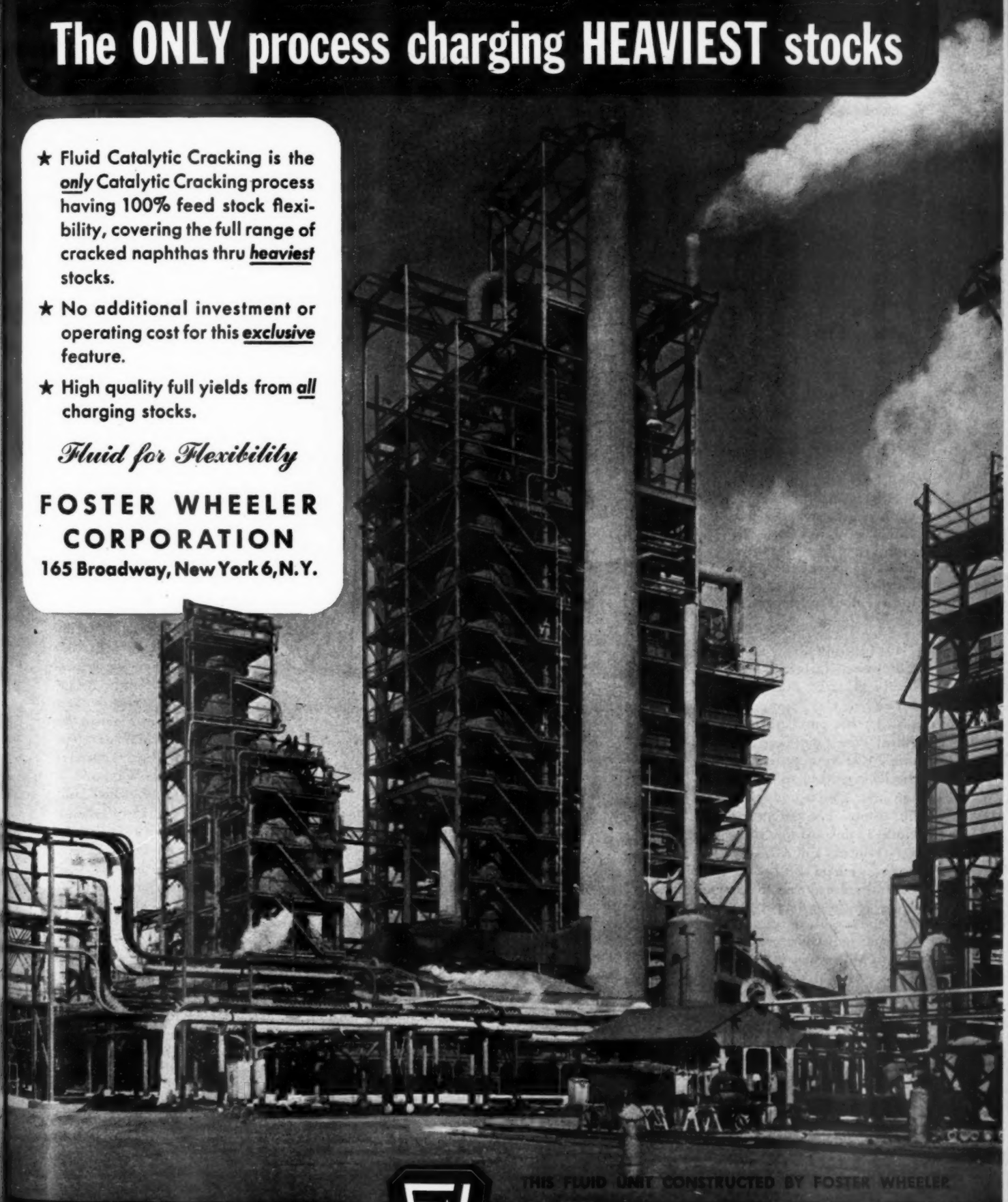
★ Fluid Catalytic Cracking is the *only* Catalytic Cracking process having 100% feed stock flexibility, covering the full range of cracked naphthas thru *heaviest* stocks.

★ No additional investment or operating cost for this *exclusive* feature.

★ High quality full yields from *all* charging stocks.

Fluid for Flexibility

FOSTER WHEELER CORPORATION
165 Broadway, New York 6, N.Y.



THIS FLUID UNIT CONSTRUCTED BY FOSTER WHEELER

FOSTER FW WHEELER

MAJOR *Pipe Line* ACTIVITIES

THE UNITED STATES now is building oil tankers 10 times faster than the enemy can sink them, Ralph K. Davies, deputy petroleum administrator, said. The situation is the reverse of what it was over a year ago, he stated, when tankers were being sunk 10 times faster than they were being built.

In the maritime commission report for November production of merchant shipping the following figures on tankers were given: 19 standard maritime commission tankers, 17 emergency tankers, and one private coastal tanker.

Construction of the Tennessee Gas and Transmission Company's natural gas pipe line from South Texas to West Virginia is going ahead steadily, according to Gardiner Symonds, president. Pipe for all river crossings is said to have been delivered and main line pipe is being received at the rate of five miles per day. Some of the main line is now being strung and welded.

Outside of Texas there has been little or no difficulty in obtaining right-of-way, Symonds declared. The Tennessee company purchased the right-of-way held by the Hope Natural Gas Company from West Virginia to Monroe, Louisiana. Between Monroe and Corpus Christi, the company has obtained about 25 per cent of the right-of-way and expects to have all of it very soon.

Oklahoma Pipe Line Company, Tulsa, Oklahoma, a subsidiary of Standard Oil Company (N. J.) has purchased the Allied Pipe Line Corporation's gathering system in the Pickens field of Madison and Yazoo counties, Mississippi. The system includes 13 miles of line, storage facilities, and a 20-car loading rack on the Illinois-Central railroad near the town of Pickens. The Allied concern is one of the principal purchasers of crude produced in this field and it will continue to buy supplies from Pickens to meet its crude oil requirements. The Pickens field is the second largest in Mississippi, producing approximately 5000 bbl. a day. The Carter Oil Company is the principal producer.

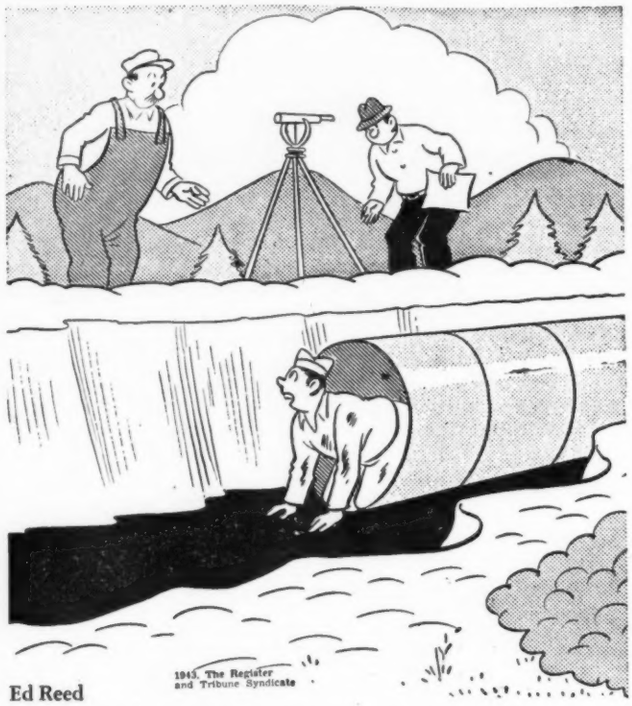
Oklahoma Pipe Line Company will establish a district office in Jackson, Mississippi, and Dallas Luttes, formerly division engineer at Wewoka, Oklahoma, will be in charge.

The "Big Inch" held a high record for deliveries during December, 1943, with shipments out of Longview, Texas, amounting to 8,745,873 bbl. of crude oil. War Emergency Pipelines, Inc., at Norris City, Illinois, diverted 459,618 bbl. via the Ohio Oil Company and Tuscarora Oil Company, Ltd., for delivery at East Coast points. Reservoir tanks in the New York and Philadelphia refining areas received 8,048,098 bbl.

Adequate pipe line capacity to move additional crude oil production being developed in the Elk Basin field in northern Wyoming was assured by Administrator Ickes. The new PAW-sponsored pipe line project from Elk Basin and Little Buffalo fields to an existing truck pipe line in Casper, Wyoming, which was approved December 7, will go into active construction as soon as weather permits, Ickes stated recently.

The new project calls for construction by the Stanolind Pipe Line Company of an 8-in. line extending the 70 miles from Elk Basin, on the Montana-Wyoming border, to Little Buffalo Basin, and a 10-in. line extending the 160 miles from there to Casper through the Stanolind line east to District 2, the midwestern, refineries; or south to refineries at Cheyenne, Wyoming, and Denver, Colorado, over the Rocky Mountain Pipe Line; or west to Salt Lake City refineries over the Utah Refining Company pipe line system, which ties in with Stanolind at Fort Laramie, Wyoming.

Capacity of the new Stanolind line, which will have two pumping stations, will be 21,500 bbl. a day into Casper. This can later be boosted to 44,000 bbl. a day by building additional pump stations. Total cost of the project is estimated at $4,200,000. It is scheduled for completion September 1, 1944.



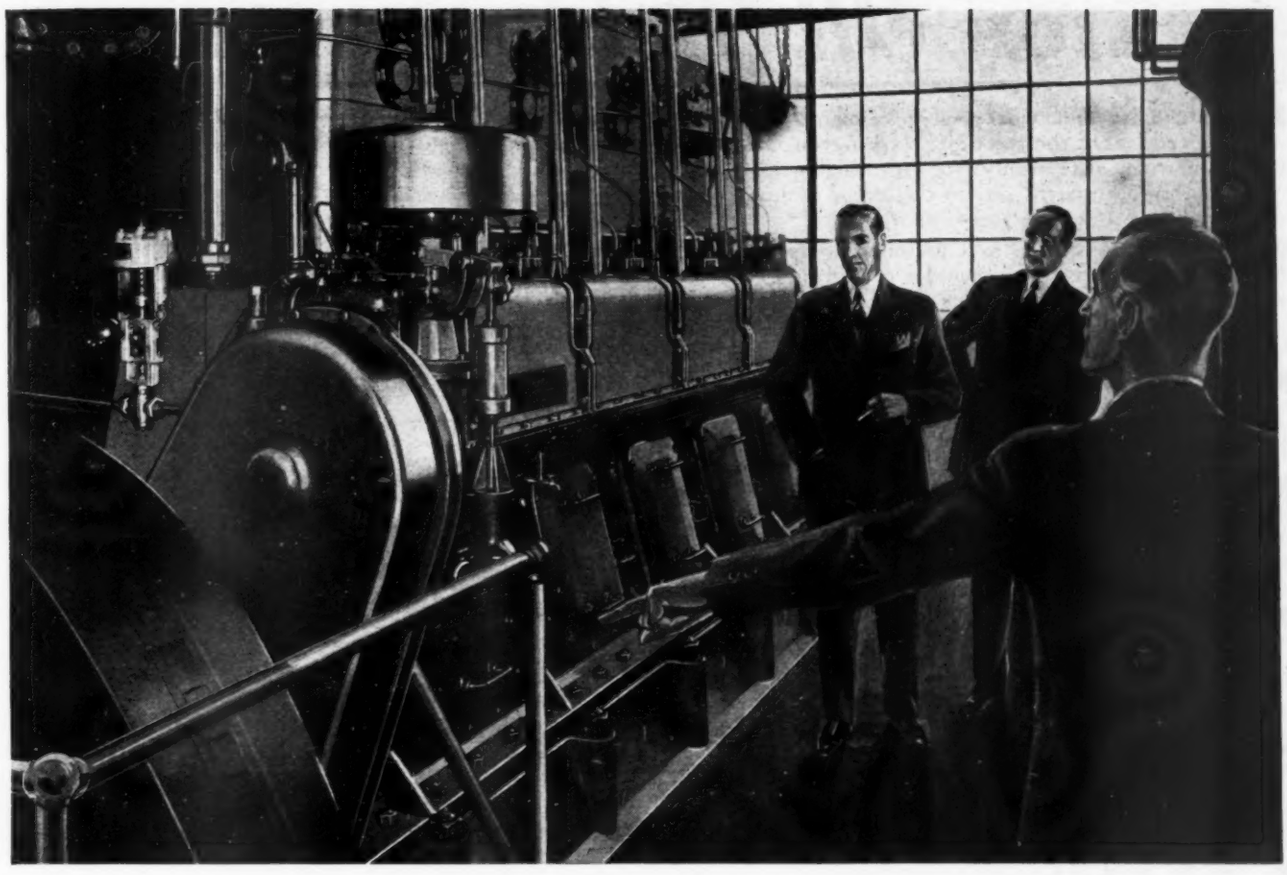
Ed Reed

"A new pipe line? I thought this was part of the obstacle course back at Camp Claiborne!"

The Independent Natural Gas Company, Bartlesville, Oklahoma, was permitted to withdraw its application to the Federal Power Commission to build a natural gas pipe line from Ray, Texas, to Milwaukee, Wisconsin. The company, which asked February 28, 1942, for the authority to construct and operate the pipe line, said it now believes construction of the 877-mile system would be currently impractical. The FPC ordered termination of the proceeding without prejudice.

The Office of Defense Transportation disclosed that the erroneous belief that the new "Big Inch" and "Little Big Inch" pipe lines have solved oil transport problems has led to a new crisis. Combined with tank truck breakdowns and home front complacency, the O.D.T. pointed out the seriousness of the situation resulting from this attitude.

In some areas, 20 per cent of all tank trucks are inoperative due to lack of tires or repair parts and this has brought about an increased demand for railway tank cars for short hauls. The pipe lines alone are not equal to meeting oil movement requirements, O.D.T. said, and shortages certain to affect the civilian economy will result unless other forms of transport continue at top efficiency.



LOW COST, Dependable Power is Yours with a Baldwin Diesel

Your best insurance for an uninterrupted power supply in stationary service installations is a Baldwin Diesel Engine. Engineered and designed to meet individual requirements, Baldwin Diesels are answering many of today's production problems by providing low cost power in industrial plants throughout the nation.

Baldwin built the first commercially successful oil engine in 1893 and since that time has manufactured diesel engines for practically every application. The experience gained in countless diesel installations in central stations, cold storage plants, mills, mines, and public buildings is utilized in solving every new power problem.

Built in sizes ranging from 200 bhp to 1,500 bhp, Baldwin Diesels feature low maintenance cost, reduced fuel consumption, sturdy, simple construction, and unusual quietness of operation.

Every Baldwin Diesel Engine is put under a full load test and given a final check-up before leaving the shop to insure extra protection in every part. Consult a Baldwin engineer regarding your specific power requirements. The Baldwin Locomotive Works, Philadelphia, Pennsylvania, U. S. A.

BALDWIN
DIESEL ENGINES

MAJOR *Oil Field* ACTIVITIES

▶ **Oklahoma.** Indications point to an important discovery of a deep pool near the town of Washington in McClain County. Carter Oil Company No. 1 Cottingham, C SE SW 4-7n-3w, had a saturated core in the second Wilcox, which was found from 10,633 to 10,641 ft.

▶ **Texas.** Humble Oil and Refining Company No. 1 Kountze, Smyth survey, has opened a new shallow pool near Rockland, Tyler County. Flowing about 50 bbl. daily of 34 gravity oil from 3429-77 ft., the producing sand has not been identified.

▶ **Kansas.** A new pool opener for Rooks County is the Continental Oil Company No. 1 Brueggeman, a wildcat in NEC 5-10-20w. Preliminary tests produced 50 bbl. an hr. from the Arbuckle at 3823-43 ft.

▶ **Mexico.** A new well, the No. 12 Mecatepec, was brought in as an addition to the famous Poza Rica oil field at a depth of nearly 3000 ft. with an initial production of 10,000 bbl. Petroleos Mexicanos, the government oil industry, reported that drilling will increase this year.

▶ **Kansas.** Margay Oil Corporation No. 1 Anderson, a wildcat strike in CNW SW 3-16-3w, which gives Saline County a new pool, has been assigned a pumping potential of 413 bbl. of oil daily. Production is through perforations from the Viola sand at 3363-66 ft.

▶ **Indiana.** Bennett Brothers No. 1 Spencer, NE SE SW 32-6s-14w, has opened a pool 3½ miles west of the Mt. Vernon pool. In early tests the well yielded 15 bbl. of oil per hr. from Tar Springs sand, flowing through casing. Later tests were not as good.

▶ **Texas.** South El Campo field is the name of a new pool opened by Seaboard Oil Company No. 1 Duson, E. T. Railway survey, section 49, 4½ miles south of El Campo. The well flowed 155 bbl. daily in a test run through perforations at 6150-54 ft.

▶ **Texas.** An important strike for the lower coast is the Humble Oil and Refining Company No. 1 Scott and Hopper, in Brooks County. The first gauge showed production of 180 bbl. daily of 44.2 gravity oil through perforations in Vicksburg sand at 6850-6905 ft.

▶ **Louisiana.** Opening of a new gas-condensate field by Union Oil of California No. A-1 State-White Lake, lease 540, in the northwest portion of White Lake, T-14s-2w, is reported. It is believed that it may make a commercial oiler. Total depth is 12,000 ft., bottomed in the Miocene.

▶ **Texas.** On potential test The Texas Company No. 1 Mains, section 16, block 8, H. and T. C. survey, flowed 400 bbl. of oil in 24 hr. The new Gunsite lime discovery in western Wilbarger County was completed through 57 casing perforations from 2786 ft. to 2796 ft. after treating with 1000 gal. of acid.

▶ **Louisiana.** Final gauge on Amerada Petroleum Corporation No. 1 Bertinot-Quebedeaux, wildcat discovery well in the Arnaudville, St. Martin Parish, is 70 bbl. of 42.5 gravity oil daily. Production came through a 5/32 in. choke from 10,349-78 ft.

▶ **Kansas.** Phillips Petroleum Company No. 1 Click, which opened the Click pool in SEC NE 2-18-7w, Rice County, was completed for 112 bbl. of oil daily from Simpson sand at 3186 ft.

▶ **Mississippi.** The Gulf Refining Company No. 1 Morrison is a new wildcat discovery well in 30-1n-13e, near Heidelberg, Jasper County. On a 15 min. drillstem test at 4910-36 ft. it made 870 ft. of 20 gravity black oil, free of water. There was also a sand showing oil at 4746-63 ft.

▶ **Kansas.** Barber County was given a new pool by Deep Rock Oil Corporation No. 2 Skinner, SWC SE 29-31-14w, several miles from production. In a 16 hr. pumping test the well made 151 bbl. of oil from Viola lime at 4624-40 ft.

▶ **Indiana.** Sells Petroleum Company No. 1 Wade, SE SW NE 14-5s-14w, appears to be a pool opener 1½ miles southeast of the New Harmony pool in Posey County. On a drillstem test the well filled with 1340 ft. of oil from Hardinsburg sand at 2455-69 ft.

AVERAGE CRUDE OIL PRICES

California	
Kettleman Hills	$1.23-1.29
Playa Del Rey	.80- .87
Coalinga	.73-1.13
Wilmington	.68-1.24
Montana	1.00-1.15
Wyoming	.45-1.15
Colorado	1.05-1.07
New Mexico	.70-1.15
Texas	
North Central	.97-1.25
Panhandle	.70-1.12
West Texas	.80-1.27
Gulf Coast	.93-1.48
Darst Creek	1.14
East Texas	.80-1.27
Talco	.79
Kansas	.93-1.25
Oklahoma	.75-1.25
Arkansas	.94-1.36
Louisiana	
Rodessa	$ .88-1.20
Gulf Coast	.93-1.36
North Louisiana	.98-1.30
Illinois	1.22-1.37
Kentucky	1.32-1.43
Indiana	.85-1.25
Ohio	
Lima	1.50-1.60
Michigan	1.24-1.44
Pennsylvania	
Bradford	3.00
Southwest	2.65
Eureka	2.59
Buckeye	2.30
Corning	1.31

DAILY AVERAGE CRUDE OIL PRODUCTION

Data Supplied by A.P.I.

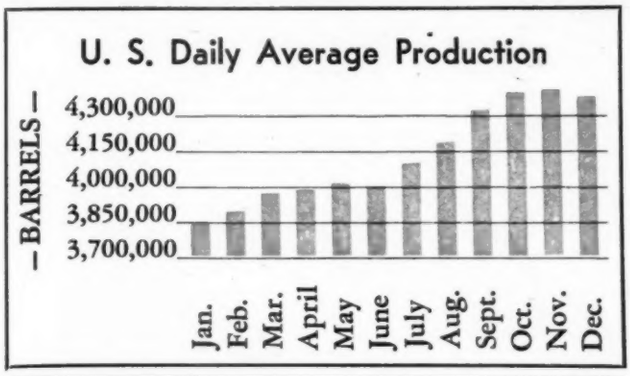
(Figures in bbl. of 42 gal. each)

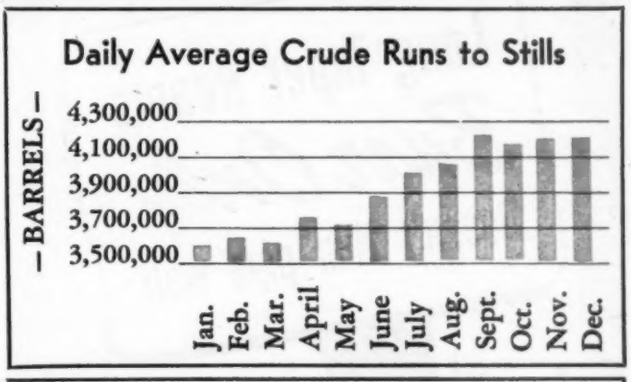
	[1]P.A.W. Recommendations December	ACTUAL PRODUCTION Week ended Dec. 25, 1943	Week ended Nov. 27 1943	Week ended Dec. 26, 1942
Oklahoma	330,000	[2]329,050	325,800	354,850
Kansas	285,000	[2]269,900	273,200	295,900
Nebraska	1,500	[2] 1,600	1,700	3,000
Panhandle Texas		94,400	85,500	93,200
North Texas		143,400	141,900	139,900
West Texas		354,400	359,750	209,300
East Central Texas		126,900	142,950	101,500
East Texas		364,300	376,400	358,600
Southwest Texas		290,800	298,100	174,000
Coastal Texas		520,500	524,600	313,650
TOTAL TEXAS	1,892,000	1,894,700	1,929,200	1,390,150
North Louisiana		78,050	78,800	92,600
Coastal Louisiana		275,500	272,200	223,000
TOTAL LA.	353,700	353,550	351,000	315,600
Arkansas	76,900	79,200	78,450	73,350
Mississippi	48,000	47,450	49,650	56,550
Illinois	215,000	213,550	218,100	234,800
Indiana	14,400	13,250	13,500	14,850
Eastern	77,000	68,700	69,850	71,000
Kentucky	25,500	22,000	24,550	16,000
Michigan	57,000	50,800	53,750	59,800
Wyoming	100,000	86,100	102,850	89,900
Montana	23,500	20,350	21,300	22,550
Colorado	7,000	6,900	7,350	6,950
New Mexico	110,600	112,900	112,900	93,350
TOTAL EAST OF CALIF.	3,617,100	3,570,000	3,633,150	3,098,600
California	808,000	792,500	780,500	782,100
TOTAL U. S.	4,425,100	4,362,500	4,413,650	3,880,700

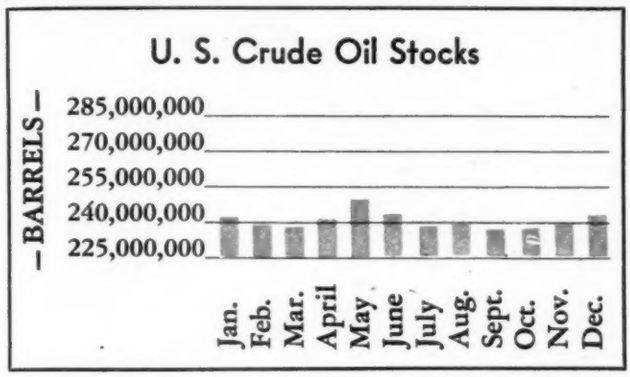
[1]P.A.W. recommendations and state allowables represent the production of crude oil only, and not condensate and natural gas derivatives to be produced.

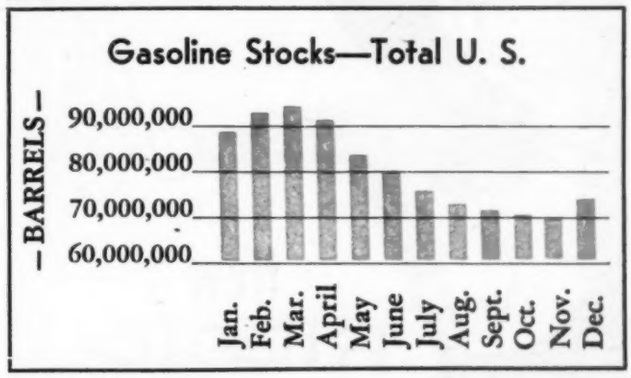
[2]Oklahoma, Kansas, Nebraska figures are for week ended 7:00 a. m., December 23, 1943.

PETROLEUM *Statistics* AND FIELD *Operations*









*Above statistics by American Petroleum Institute.

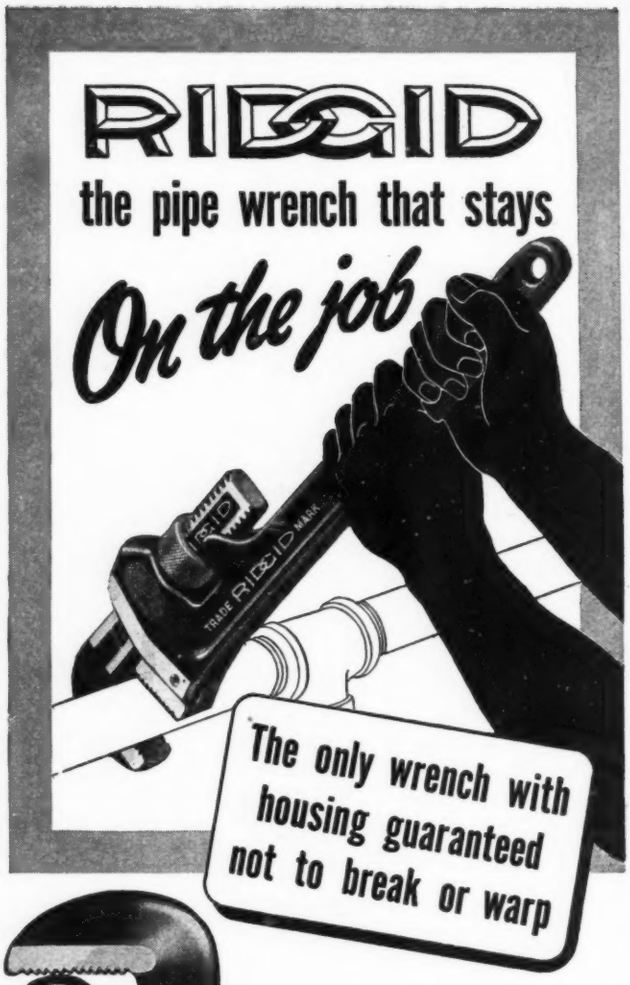
Summarized Operations in Active Fields for December, 1943

Fields	Completions	Producers	Rigs	Drilling Wells	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
TEXAS								
Eastern Texas	21	14	11	....	3500-3700	2	40	Rotary
Gaines County	31	3	4	....	4400-5594	2	22-35	Rotary
Hockley County	12	9	8	....	4800-6850	2	20-30	Rotary
Ector County	15	13	7	....	3675-4377	2 or 3	32-36	Rotary
Panhandle	15	11	6	....	1700-3900	2	40	Rot.-Cab.
Nueces County	9	7	8	....	3922-5878	2 or 3	21-54	Rotary
K. M. A. Field	13	9	4	....	3730-3935	2	42-43	Rot.-Cab.
Hawkins Field	10	7	7	....	4495-4912	2	19-29	Rotary
OKLAHOMA								
Okfuskee County	6	3	4	....	2150-4125	2 or 3	38	Rotary
KANSAS								
Russell County	11	9	4	....	2926-3435	2 and 5	32-37	Rot.-Cab.
Rice County	8	7	3	....	3222-4085	2 and 5	42-48	Rot.-Cab.
Barton County	6	3	4	....	3290-3518	2	39-42	Rot.-Cab.
ILLINOIS								
Central Illinois	148	136	91	100	1425-4100	2	36-38	Rot.-Cab.
NEW MEXICO								
Lea County	4	3	4	....	3150-4030	2	30-34	Rot.-Cab.
CALIFORNIA								
Kern County	11	9	10	4	1840-11,450	2 or 4	14-30	Rotary
Wilmington County	14	11	17	14	3500-4000	2 and 3	18-20	Rotary

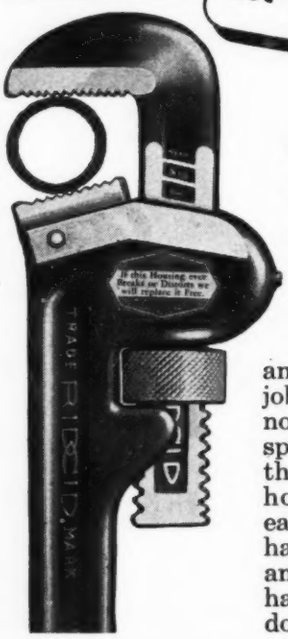
Field Activities by States for December, 1943

	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1942 (In barrels)
	December	November	December	November	December	November	December	November	December	November	
Arkansas	20	22	11	18	17	36	8	15	14	27	26,560,000
California	77	131	69	120	61	84	31	43	22	43	248,250,000
Illinois	148	151	136	117	84	90	91	96	100	104	105,768,000
Indiana	40	38	33	23	27	42	7	12	15	14	6,680,000
Kansas	185	184	141	121	48	51	22	40	13	....	96,920,000
Kentucky	58	69	37	47	15	26	....	66	....	....	4,503,000
Louisiana	45	46	33	35	22	28	9	21	17	30	125,450,000
Michigan	52	57	42	46	24	27	12	17	15	....	21,568,000
Mississippi	3	2	2	....	....	....	....	....	....	....	27,605,000
Montana	14	15	6	9	....	....	4	....	....	....	8,998,000
Nebraska	....	1	....	....	4	8	....	....	....	....	1,367,000
New Mexico	22	24	16	15	12	14	....	....	....	....	31,875,000
New York	102*	111*	100*	80*	50	53	24	....	....	....	5,132,000
Ohio	62	60	53	45	33	43	20	....	....	....	3,480,000
Oklahoma	120	123	94	84	45	51	20	14	50	56	138,750,000
Pennsylvania	206*	212*	179*	126*	155	182	....	....	....	....	17,256,000
Texas	340	344	281	267	305	300	245	306	303	310	476,560,000
West Virginia	64	73	56	62	25	29	4	3	16	5	3,780 000
Wyoming	6	5	5	3	4	4	2	1	12	1	32,776,000
Total	1557	1668	1294	1918	931	1068	409	634	577	590	1,383,280,000

*Includes water-intake and pressure wells.



● This new long-taper reamer removes the burr only, reams easily, will not thin or split wall of pipe or conduit. The long-taper does it — and does it easily, with feather-light ratcheted strokes, saving you time and effort. RIDGID long-taper LonGrip Reamer comes complete with ratchet handle or you can buy reamer unit alone for use in RIDGID No. 00R threader handle, as shown at left. Capacity ⅛" to 2". For easy *safer* reaming — ask your Supply House for this new long-taper RIDGID Reamer. Immediate delivery.



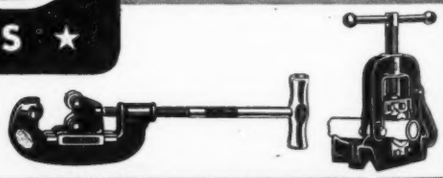
● That famous RIDGID housing guarantee assures you far more than replacement of the housing free if it ever breaks or warps. It means that millions of these wrenches in service have proved that nothing goes wrong with the housing — and the wrench stays on the job. No housing repair expense, no tools out of service, fewer spares needed. You'll like also the adjusting nut in open housing that always spins easily to pipe size — and the handy pipe scale on hookjaw — and the comfort-grip I-beam handle. Keep work up, costs down — ask your Supply House.

Sold by Supply Houses Everywhere

RIDGID
★ PIPE TOOLS ★

Millions of RIDGID Tools in use

THE RIDGE TOOL COMPANY
Elyria, Ohio, U. S. A.



THE Petroleum Engineer

JANUARY, 1944

Domestic Oil Shortage— A Challenge to the Oil Industry

PETROLEUM ENGINEER Exclusive Feature

☆ Discovering new oil reserves six times less successful in 1943 than in 1935

by H. J. Struth
Petroleum Economist

ALL-OUT war efforts of the American petroleum industry in 1943 boosted crude oil production to an all-time high annual record of 1,508,306,000 bbl., a gain of more than 121,000,000 bbl. over the preceding year. In establishing this record, however, many of the oil producing states were confronted with the realization that their field production schedules had been maintained at rates greater than maximum efficient capacities.

Most significant, and perhaps of greatest concern to the oil industry and the nation at war, is the realization that for the fifth consecutive year the oil industry failed to find new oil reserves in sufficient quantity to offset heavy withdrawals from the underground reservoirs. In fact, there was a deficit last year of more than one billion barrels in new reserve discoveries, and over the last five years the deficiency between demand and new supply has amounted to 3,600,000,000 bbl. During the first world war period the oil industry discovered 160 bbl. of new oil for each 100 bbl. of oil produced, but today the industry is able to find only 28 bbl. of new oil for each 100 bbl. produced.

The uneasy situation in which the oil industry finds itself today is not a new experience in its long and colorful history. Many times in the past, when periods of overproduction and low oil prices were followed by protracted

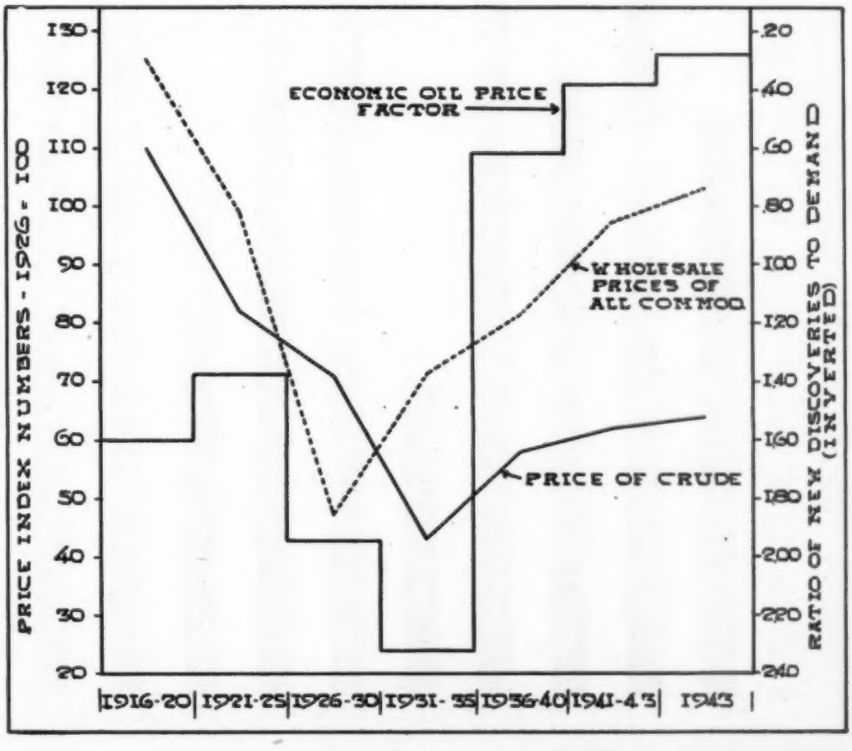


Fig. 1. Price of crude oil as related to wholesale commodity prices and oil industry's economic position. On a parity basis crude price level is 77 cents below wholesale price level of all commodities. On a relative economic basis the crude oil price level is apparently $1.40 below true value. (Details are presented in Table 1.)

periods of failure to discover and develop new sources of supply, the natural laws of supply and demand provided the necessary stimulus to exploratory effort through the medium of an adequate price for crude oil. What is new to the oil industry in this respect today is the failure of those who have laid down the rules for the oil industry to follow, to recognize the natural economic impulses that govern underlying causes and effects within the oil industry.

Prices Affect Drilling

A study of ratios of new oil discoveries to demand for crude oil over the last 28 years has definitely established the fact that when new oil supplies consistently overbalance demand, economic forces tend to depress the price of crude oil. Inversely, when new discoveries fall consistently below demand crude oil prices move upward and serve as a stimulus to renewed exploratory effort. Fig. 1 makes it apparent that the downward trend in oil prices following the first world war period was a natural course of events dictated by a consistently growing surplus of new oil discoveries. The underlying reason for these surplus discoveries was high oil prices, which reached an average of $3.07 per bbl. in the year 1920. In that year the oil industry drilled approximately 34,000 wells. Last year, with oil selling at $1.20 per bbl., the industry drilled less than 18,000 wells.

The economic oil price factor, which is the ratio of new discoveries to demand, inverted, prescribed a downward trend for oil prices that extended through 1935. The next five-year period, however, brought a reversal in the trend of the oil price factor, marking the beginning of failure of new oil discoveries to keep pace with the growing demand for crude oil. This trend became sharply accelerated within the last three years as a result of constantly

TABLE I

Ratio of new oil discoveries to demand and crude price relationship

(Annual averages)

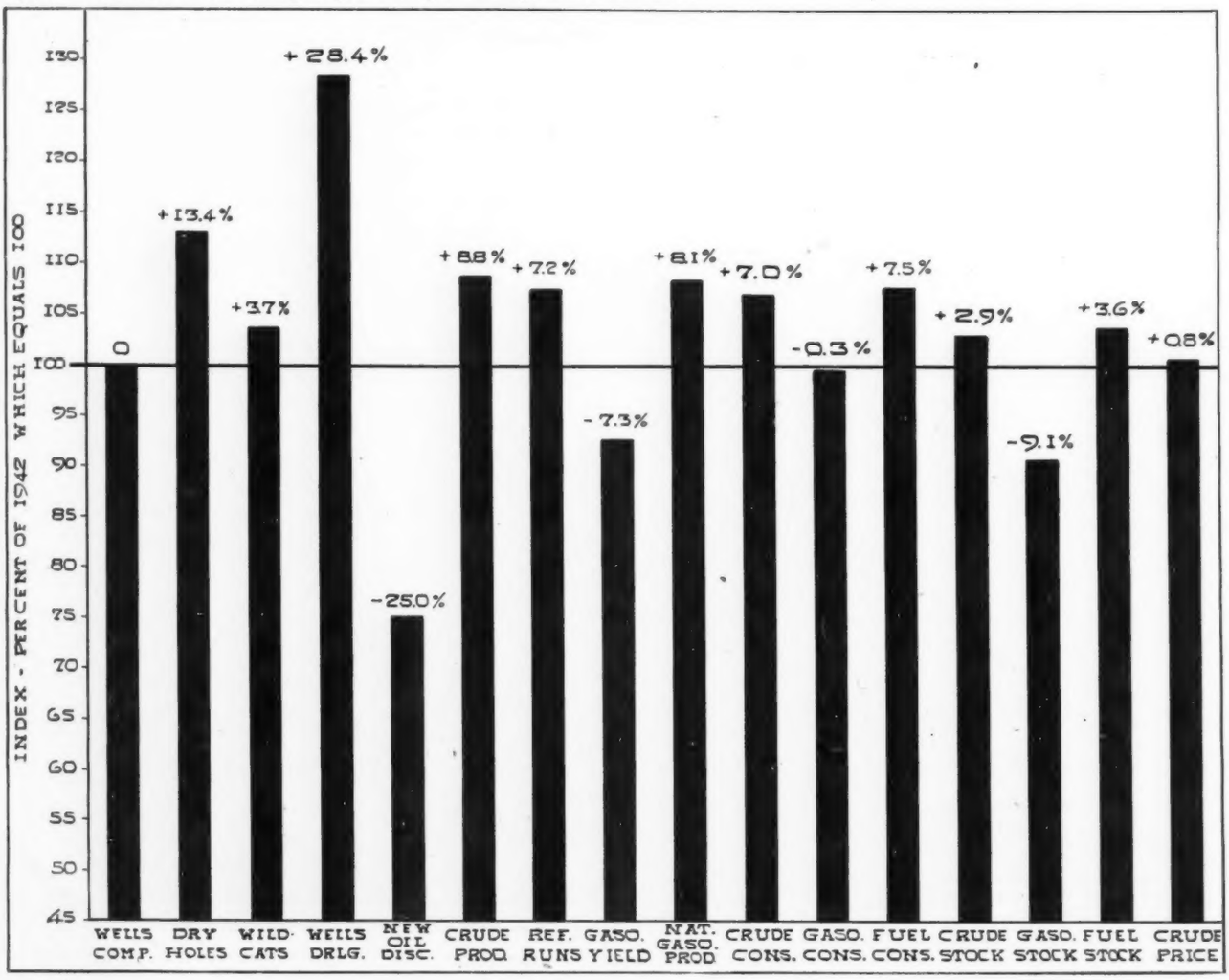
Period	New oil supply discovered (million bbl.)	Crude oil demand (million bbl.)	Surplus or shortage (million bbl.)	Supply-demand ratio	Wholesale price index†	Price of crude oil
1916-20	660	412	+ 248	1.60	125.5	$2.07
1921-25	970	705	+ 265	1.37	99.3	1.54
1926-30	1840*	950	+ 890	1.93	47.5	1.34
1931-35	2200	946	+1254	2.32	71.7	.83
1936-40	790	1282	— 492	.61	80.3	1.09
1941-43	553	1463	— 910	.38	97.0	1.17
Year 1943 (p)	420	1510	—1090	.28	105.0	1.20

*5 billion bbl. discovered in East Texas at close of 1930 credited to 1931-35 period since full effect of huge new supply was not reflected in price structure until 1931.

†U. S. Bureau of Labor Index—1926—100.

(p) Preliminary—subject to final revision.

Fig. 2. United States petroleum situation—year 1943 compared with 1942. Columns are relative to heavy horizontal line (100), which represents level of each factor during the year 1942. (Details are presented in Table 2.)



smaller discoveries and greatly increased war demand. If economic laws had been permitted to function freely, the price of crude oil might by this time have advanced to $2.60 per bbl., against today's average price of $1.20.

Granting the fact that some form of price control is necessary to prevent inflation during the war period, it is obvious from a study of the facts presented here that crude oil prices were frozen at levels that actually were far below intrinsic values. As a matter of fact, even if crude oil prices had been maintained at a level consistent with all wholesale commodity prices, the average price of crude oil should now have been $1.97, or 77 cents above the current price level.

National Oil Situation

Outstanding changes recorded in the national oil situation last year were an increase of 4.1 per cent in the dry hole ratio; an increase of 28 per cent in the number of new wells drilling at the close of the year; a further decline of 25 per cent in new oil reserves discovered; an increase of more than 8 per cent in crude oil production; an increase of 7 per cent in refinery crude runs to stills; a further drop of approximately 3 per cent in the gasoline yield from crude oil, and the fact that for the first time in the oil industry's history the demand for fuel oil exceeded the demand for gasoline. These and other facts for last year are compared percentage-wise with 1942 in Fig. 2. The preliminary figures of 1943 and two preceding years, together with stock changes and price comparisons, are presented in Table 2.

Particular emphasis attaches to the effect of reduced gasoline yields upon the war demand for crude oil. If refiners had been able to maintain prewar gasoline production schedules, on the basis of a 45 per cent yield instead of about 37 per cent, the demand for crude oil might have been about 250,000,000 bbl. less than was actually consumed last year. This is a startling realization in view of the critical reserve discovery situation confronting the oil industry at this time.

In terms of daily average crude production, this extra demand amounts to 685,000 bbl., which difference has already had a far-reaching effect upon the efficient productive capacity of wells in many of the nation's oil fields. Yet, it is this difference that is making possible the production of needed war products and as a result is making less motor fuel available for civilian use. With the prospect of five million of our armed forces overseas by summer and a demand for crude oil of at least 1,625,000,000 bbl. this year the outlook for the oil industry is expected to become extremely critical. With many oil states

TABLE 2—United States petroleum situation
(Year 1943 compared with 1942 and 1941)

	1941	1942	1943 (p)	Index (1942=100)	Percent change
Total wells drilled	29,070	17,934	17,941	100.0	0
Oil wells	19,175	10,302	9,811	95.2	— 4.8
Gas wells	2,990	2,100	1,857	88.4	—11.6
Dry holes	6,885	5,532	6,273	113.4	+13.4
Per cent dry	23.6	30.8	34.9	..	+ 4.1
Wildcat wells drilled	3,160	3,250	3,369	103.7	+ 3.7
Producers	518	591	538	91.0	— 9.0
Dry holes	2,700	2,598	2,753	106.0	+ 6.0
Per cent dry	85.4	80.0	81.7	..	+ 1.7
Wells drilling (December 31)	3,993	2,313	2,969	128.4	+28.4
Crude oil production (thousands)	1,402,228	1,386,645	1,508,306	108.8	+ 8.8
Daily average (thousands)	3,842	3,799	4,132		
New oil discovered (thousands)	680,000	560,000	420,000	75.0	—25.0
Refinery still runs (thousands)	1,409,192	1,334,103	1,430,120	107.2	+ 7.2
Daily average (thousands)	3,861	3,655	3,918		
Gasoline yield from crude	44.2	39.7	36.8	92.7	— 7.3†
Natural gasoline production (thousands)	80,855	83,322	90,060	108.1	+ 8.1
Daily average (thousands)	222	228	247		
Crude oil demand (thousands)	1,471,771	1,410,866	1,509,704	107.0	+ 7.0
Daily average (thousands)	4,032	3,865	4,136	107.0	+ 7.0
Motor fuel demand (thousands)	694,253	624,092	622,279	99.7	— 0.3
Daily average (thousands)	1,902	1,710	1,705		
Fuel oil demand (thousands)	544,841	603,792	649,084	107.5	+ 7.5
Daily average (thousands)	1,493	1,654	1,778		
Crude oil stocks (thousands)					
January 1	276,615	257,678	245,754	95.4	— 4.6
December 31	257,678	245,754	252,810	102.9	+ 2.9
Change	—18,937	—12,924	+7,056		
Days supply, December 31	64	64	61		
Motor fuel stocks (thousands)					
January 1	83,647	90,596	75,404	83.2	—16.8
December 31	90,596	75,404	68,600	90.9	— 9.1
Change	+6,949	—15,192	—6,804		
Days supply, December 31	48	44	40		
Fuel oil stocks (thousands)					
January 1	130,937	132,289	106,723	80.7	—19.3
December 31	132,289	106,723	110,530	103.6	+ 3.6
Change	+1,352	—26,398	+3,807		
Days supply, December 31	89	62	65		
All refined oil stocks (thousands)					
January 1	280,958	294,310	247,554	84.1	—15.9
December 31	294,310	247,554	243,700	98.4	— 1.6
Change	+13,352	—46,756	—3,854		
Days supply, December 31	79	67	64		
Crude oil prices (December 31)					
U. S. average	$1.14	$1.19	$1.20	100.8	+ 0.8
Mid-Continent 36 gr	1.17	1.17	1.17	100.0	0
East Texas	1.25	1.25	1.25	100.0	0
Bradford (Pennsylvania)	2.75	3.00	3.00	100.0	0
California 26 gr. Signal Hill	1.11	1.11	1.11	100.0	0
California heavy crude	.73	.73	.98	135.1	+35.1
Refinery product prices (December 31)					
Motor gasoline, Group 3	6	5⅞	5¾	97.9	— 2.1
Motor gasoline, New York	8	6⅛	9.2	150.2	+50.2
Motor gasoline, Gulf Coast	6¼	5¾	5¾	100.0	0
Motor gasoline, California	5½	6¼	6	97.9	— 2.1
Kerosine, 41-43, Group 3	4⅜	4⅜	4⅜	100.0	0
Kerosine, New York	5.3	6.8	7	102.9	+ 2.9
Furnace oil, Group 3	3⅜	3½	3½	100.0	0
Bunker C. fuel oil, New York	$1.45	$1.65	$1.65	100.0	0
Natural gasoline, Group 3	5¼	3⅞	4¾	122.6	+22.6
Natural gasoline, California	4½	4⅞	4⅞	100.0	0

(p) Preliminary—subject to final revision.
†Relative decrease. Actual percentage change from 1942 was 2.9 per cent.

TABLE 3—United States crude oil situation—1942 and 1943

	1943 (p)	1942	Change from 1942
Stocks, January 1	245,754,000	257,678,000	— 11,924,000
Production	1,508,306,000	1,386,645,000	+121,661,000
Total	1,754,060,000	1,644,323,000	+109,737,000
Refinery runs	1,430,120,000	1,334,103,000	+ 96,017,000
Used as fuel, including transfers to fuel oil	42,960,000	38,000,000	+ 4,960,000
Stocks, December 31	252,810,000	245,754,000	+ 7,056,000
Total	1,725,890,000	1,617,857,000	+108,033,000
Balance of foreign trade*	+ 28,170,000	+ 26,466,000	+ 1,704,000
Indicated demand	1,509,704,000	1,410,866,000	+ 98,838,000

*Export and import figures are not available. This is balancing figure, which represents approximate difference between imports and exports. The plus sign indicates an excess of exports over imports.
(p) Preliminary—subject to final revision.

TABLE 4—United States motor fuel situation—1943 and 1942

	1943 (p)	1942	Change from 1942
Stocks, January 1	75,404,000	90,596,000	—15,192,000
Production	615,475,000	608,900,000	+ 6,575,000
Total	690,879,000	699,496,000	— 8,617,000
Stocks, December 31	68,600,000	75,404,000	— 6,804,000
Indicated demand	622,279,000	624,092,000	— 1,813,000

(p) Preliminary—subject to final revision.
Note: Imports have been negligible. Export figures not available.

already producing oil in excess of efficient rates, a further increase in daily oil production of 318,000 bbl. presents a disturbing problem for the oil industry in 1944. The dwindling capacity of existing wells to produce, as a direct result of deficient discoveries, can probably only be solved by imports of South American oil. Furthermore, the increased utilization of crude oil this year, necessarily devoted to the production of war products, may provide less rather than more gasoline for civilian motorists.

Demand at All-Time High

Table 3 presents a summary of the national crude oil situation for 1943 and 1942. It shows that the demand for crude reached an all-time high record of about 1,510,000,000 bbl., an increase over 1942 of nearly 100,000,000 bbl. Table 4 shows that despite the huge increase in refinery crude runs gasoline production was increased only about one per cent over 1942. It also shows that severe rationing of civilian gasoline caused a decline of only 1,813,000 bbl. last year. Thus represented a drop of only three-tenths of one per cent under 1942. Increased military motor fuel requirements apparently offset what might otherwise have been lost to the industry in civilian gasoline gallonage.

The gasoline stock situation showed that although stock withdrawals were less than half those of 1942, stocks at the close of the year represented only 40 days' supply, against 44 days' supply at the end of 1942. Table 5 shows that the demand for fuel oil exceeded production by about 23,000,000 bbl. last year, against a deficit in the preceding year of about 48,000,000 bbl. Indicated demand, including transfers to crude oil but not considering imports and exports, increased more than 45,000,000 bbl. last year.

The precipitous decline in new oil discoveries that followed East Texas in 1930 and the extent to which demand for crude oil has outdistanced new discoveries since 1938 are charted in Fig. 3. These data, taken from Table 6, have been computed in terms of five-year moving averages, which serve to eliminate erratic year-to-year fluctuations. The relationship of crude oil price movements to discoveries and demand further emphasizes the fact that crude oil price ceilings established by the Office of Price Administration as of October

TABLE 5
United States fuel oil situation
1943 and 1942

	1943 (p)	1942	Change from 1942
Stocks, January 1	106,723,000	133,121,000	—26,398,000
Production	626,146,000	555,615,000	+70,531,000
Transfers from crude	26,745,000	21,779,000	+ 4,966,000
Total	759,614,000	710,515,000	+49,099,000
Stocks, December 31	110,530,000	106,723,000	+ 3,807,000
Indicated demand	649,084,000	603,792,000	+45,292,000

(p) Preliminary—subject to final revision.
Note: Imports and exports eliminated, figures not available.

TABLE 6
Reserves discovered and demand for crude oil
(Five-year moving averages)
(1916 through 1943)

Period	Total reserves discovered (million)	Annual average (million)	Total crude oil demand (million)	Annual average (million)
1916-20	3,300	660	2,063	412
1917-21	4,450	890	2,274	455
1918-22	4,500	900	2,514	502
1919-23	5,000	1,000	2,841	568
1920-24	4,950	990	3,222	644
1921-25	4,850	970	3,526	705
1922-26	6,450	1,290	3,851	770
1923-27	6,650	1,330	4,149	829
1924-28	8,350	1,670	4,374	875
1925-29	9,400	1,880	4,617	923
1926,30	14,200	2,840	4,752	950
1927-31	12,800	2,560	4,829	966
1928-32	11,900	2,380	4,795	959
1929-33	9,700	1,940	4,749	949
1930-34	9,500	1,900	4,661	932
1931-35	6,000	1,200	4,733	946
1932-36	6,100	1,250	4,954	991
1933-37	5,975	1,195	5,383	1,076
1934-38	6,075	1,215	5,731	1,146
1935-39	4,950	990	6,088	1,217
1936-40	3,950	790	6,409	1,282
1937-41	3,780	756	6,723	1,344
1938-42	3,540	708	6,845	1,369
1939-43	3,280	656	7,087	1,417
Year 1943 (p)	420	420	1,510	1,510

(p) Preliminary—subject to final revision.

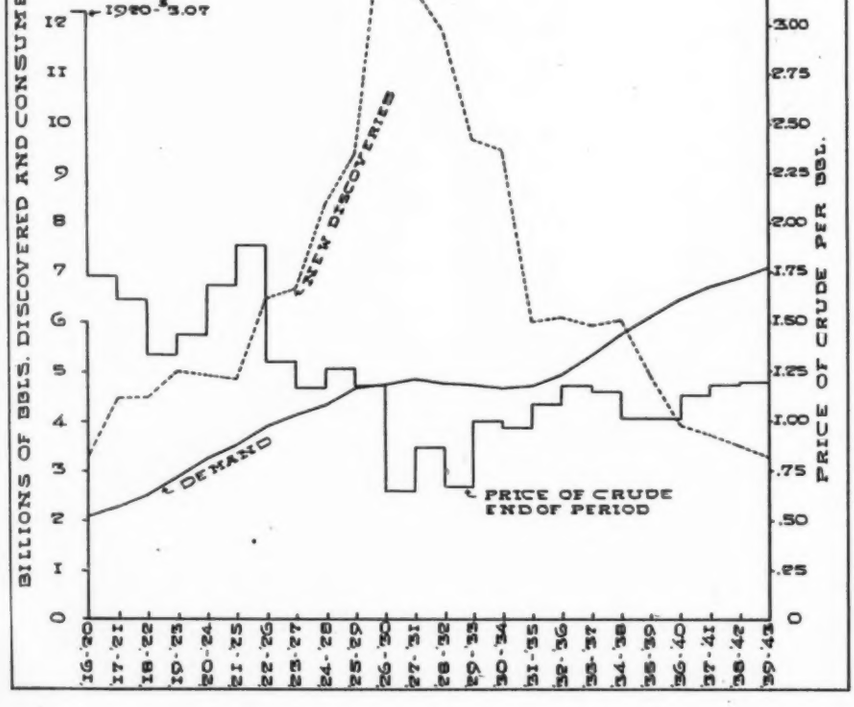


Fig. 3. Trend of new oil discoveries, demand for crude and average price of oil since 1916. *Discoveries and demand are computed in five-year moving averages. Price of crude oil is average for last year of each period.* (Details are presented in Table 6.)

1, 1941, represented a subnormal, uneconomic level.

In the light of the trend of deficiency in discoveries as related to demand, which began in 1939, it is obvious that October 1, 1941, crude oil prices could not subsequently have been sustained in the face of economic impulses that dictated the necessity for a material upward revision. Any reasons that prompted the establishment of these subnormal oil price ceilings, and particularly the continued failure to recognize the growing seriousness of the petroleum reserve situation, cannot be supported in the light of events that have proved them contrary to the best interests of the nation at war.

Disappointing Wildcat Results

Wildcatting results were even more disappointing last year than in 1942. First estimates of new oil discoveries indicate that the industry probably found only 245,000,000 bbl. of oil in new fields last year, compared with a total of about 260,000,000 bbl. in 1942. After crediting extensions and revisions to the 1942 first estimates, however, the revised figure for that year increased to about 560,000,000 bbl. Likewise, on the assumption that this year's new oil discoveries will necessarily be adjusted by subsequent extentions and revisions, the 1943 new oil discovery figure appears likely to aggregate about 420,000,000 bbl., against the revised 1942 discovery figure of 560,000,000 bbl.

Considering all exploratory effort during the last year, it appears now that the industry found, including new discoveries, extensions to previously discovered fields and revisions of first estimates, total additional reserves of about 879,000,000 bbl. More than half of this total, however, must be credited to previous discovery years. The total for 1943 compares with all reserve discoveries made in 1942 of 954,000,000 bbl. and a total of 3,613,000,000 bbl. in 1936.

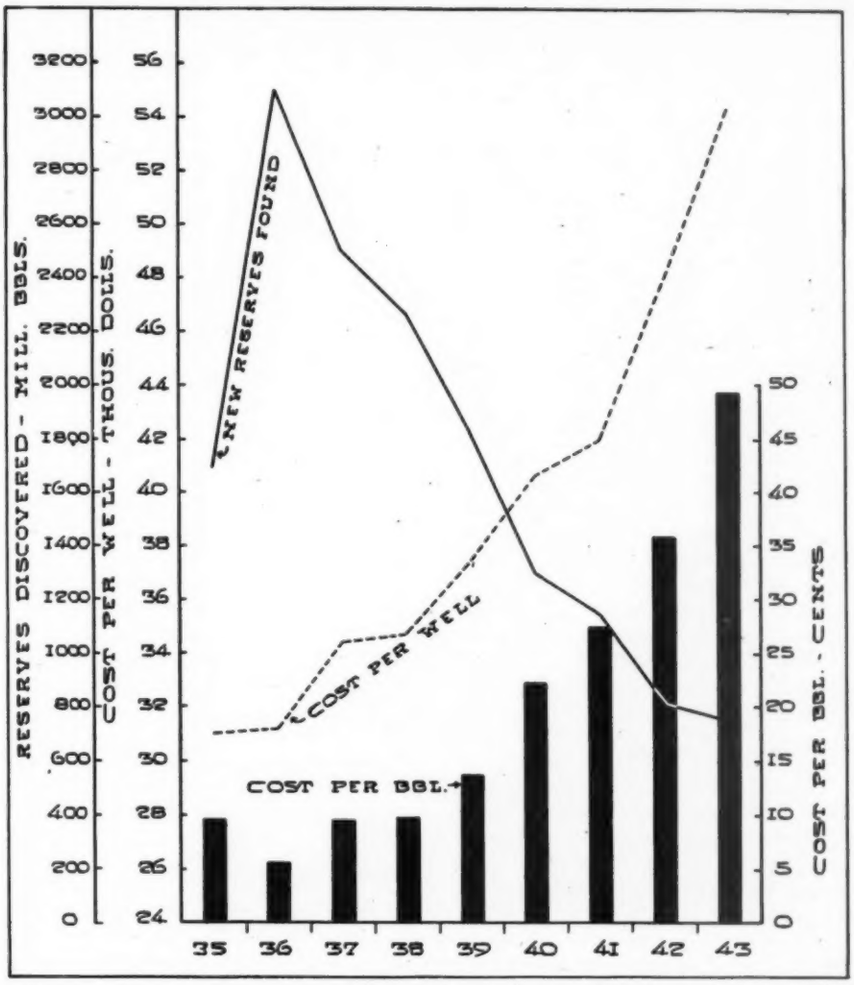


Fig. 4. Course of new reserve discoveries and cost of finding oil since 1935. ***Cost per exploratory well includes drilling, lease and overhead costs and cost of equipping producing wells. Columns show trend of finding cost per barrel for each year.*** **(Details in Table 7.)**

Fig. 4 shows the trend of reserve discoveries since 1935, the extent to which exploratory well costs including drilling and overhead costs have increased over the last nine years and estimates of the cost of finding oil per barrel for each of these years. Detailed figures upon which this chart is based are shown in Table 7. This represents a revision of earlier studies made by the author. Total discoveries for each year in this study have been computed to credit all new discoveries and extensions to the year in which costs of exploration were incurred, but allocating back all revisions in earlier estimates to the respective years in

TABLE 7

Cost of finding oil in the United States
(Years 1935 through 1943)

Year	New oil discovered* (million)	Total oil found during year, including extensions and revisions (million)†	Net working interest (million)	No. of exploratory wells drilled+	Drilling cost, (thousand dollars)	Lease and overhead cost (thousand dollars)°	Total cost, (thousand dollars)	Cost, per bbl.	Average cost, per well	Exploratory wells per million bbl.	Oil found per exploratory well (bbl.)
1935	2100	1970	1689	5231	$ 57,639	$104,620	$162,250	$0.096	$31,000	2.65	377,000
1936	1700	3613	3097	5671	63,414	113,420	176,834	0.057	31,200	1.57	637,000
1937	1975	2904	2489	6900	85,320	151,800	237,120	0.095	34,400	2.38	421,000
1938	1800	2654	2274	6453	81,750	141,966	223,716	0.098	34,700	2.43	411,000
1939	850	2120	1817	6732	90,177	161,568	251,745	0.139	37,400	3.18	315,000
1940	800	1505	1290	7032	102,644	182,832	285,476	0.221	40,600	4.67	214,000
1941	680	1330	1140	7388	125,075	185,221	310,296	0.272	42,000	5.55	180,000
1942	560	954	818	6123	121,302	172,602	293,904	0.359	48,000	6.42	156,000
1943-p	420*	879	754	6811	148,525	221,312	369,831	0.491	54,300	7.75	129,000

*Extensions and revisions credited to years of original discovery.
†Includes oil discovered in new fields and extensions to previously discovered fields. Revisions in estimates are credited to years in which estimates were necessarily revised upward.
+Includes wildcat producers and all dry holes drilled each year.
‡Cost of drilling and equipping wildcat producers and drilling cost of all dry holes.
°Includes cost of carrying and acquiring leases, geological, geophysical, and overhead cost‡
*Provides for probable extensions and revisions. New oil found in 1943 was estimated at 245,000,000 bbl.
p–Preliminary—subject to final revision.

TABLE 8

Analysis of oil reserve replacement costs

Showing effect of rising oil finding cost upon shortage in new reserve discoveries

Year	New oil discovered (million bbl.)*	Annual crude production (million bbl.)	Surplus (million bbl.)	Shortage (million bbl.)	Finding cost, per bbl.	Finding cost oil discovered in excess of requirements (thousand dollars)	Replacement cost of oil produced from reserves in excess of discoveries (thousand dollars	Net cumulative effect (thousand dollars)
1935	2,100	997	1103	....	$0.096	$105,888	.....	+$105,888
1936	1,700	1,100	600	....	0.057	34,200	.....	+ 140,088
1937	1,975	1,279	696	....	0.095	66,020	.....	+ 206,108
1938	1,800	1,213	587	....	0.098	57,526	.....	+ 263,636
1939	850	1,265	....	415	0.139	.....	$ 57,685	+ 205,949
1940	800	1,353	....	553	0.221	.....	122,213	+ 83,736
1941	680	1,402	....	722	0.272	.....	196,384	— 112,648
1942	560	1,387	....	827	0.359	.....	298,893	— 411,541
1943 (p)	420	1,508	....	1088	0.491	.....	534,208	— 945,749
Totals	10,885	11,504	2986	3605		$263,634	$1,209,383	
1935-38	7,575	4,589	2986	....	0.088	$263,634	.....	
1939-43	3,310	6,909	....	3605	0.335	.....	$1,209,383	

*Extensions and revisions credited to years of original discovery.
(p) Preliminary—subject to final revision.

which they were made. Furthermore, it was deemed advisable to compute oil finding costs per barrel on the basis of working interest barrels, rather than on gross oil to conform with standard practices within the industry. The finding cost per barrel is computed by dividing the total cost (column 7) by the working interest barrels of all oil discovered (column 3).

Finding Cost Greater

This study indicates that the industry spent last year approximately $370,000,000 in exploratory effort, or at the rate of $54,300 per exploratory well drilled. This indicates an expenditure of 49.1 cents for each barrel of working interest oil discovered last year. The 1943 cost of 49.1 cents compares with an annual average cost between 1935 and 1939 of about 9.2 cents per bbl. Attention is called to the fact that these costs are based upon all reserves discovered during each year, including extensions to previously discovered fields and include the drilling cost of all dry holes, both wildcat and development dry holes. By this or any other method, regardless of final results, it is evident that the cost of finding oil in the United States is now five times what it was between 1935 and 1939.

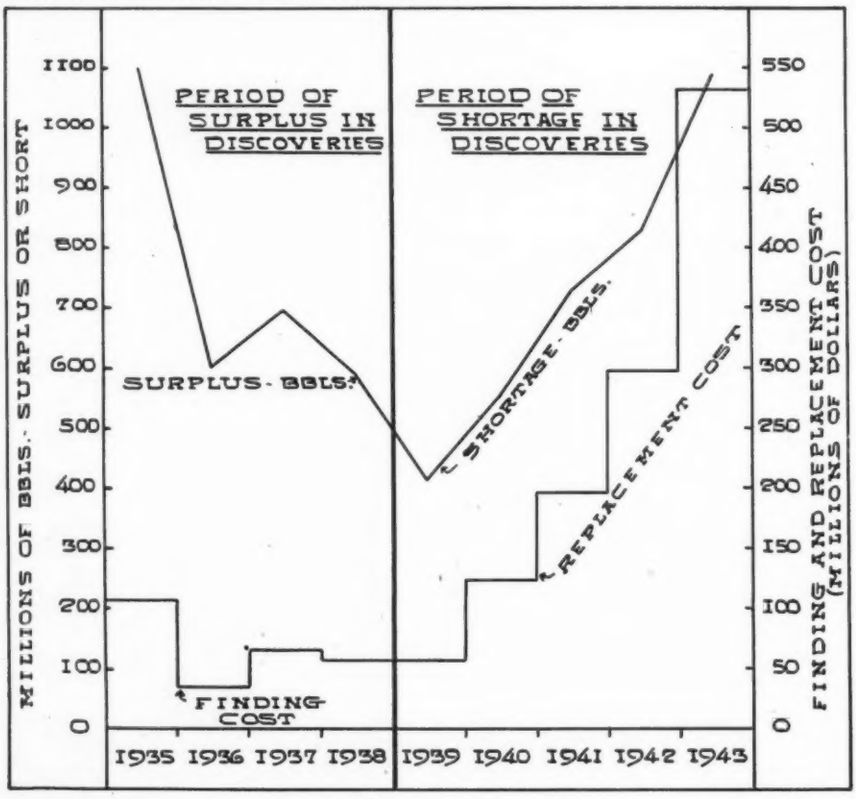
Exploration Expenditures

Expenditures for oil exploration in the United States last year were distributed about as follows:

Cost of drilling and equipping wildcat producers and drilling cost of all dry holes (6811 wells)	$148,525,000
Cost of acquiring and carrying leases	142,600,000
Geological and geophysical costs	42,500,000
General overhead cost	36,206,000
Total exploration cost	$369,831,000

Using the average discovery experience for the last three years of 155,000 bbl. of oil found per exploratory well drilled, it would appear necessary for the industry to drill about 10,500 exploratory wells in 1944 in order to find sufficient new reserves to meet the expected demand of 1,625,000,000 bbl. At current costs, which are shown to average $54,000 per well, this would entail a total expenditure in 1944 of about $570,000,000, or about $200,000,000 more than was actually spent last year. Actually, the industry found an average of only 129,000 bbl. of new reserves per exploratory well drilled last year. It will be noted in Table 7 that it took the drilling of nearly eight exploratory wells last year to find a million barrels of new oil reserves, compared with a ratio of 1.57 in 1936.

Fig. 5. Cost of replacing deficiency in new oil discoveries since 1938. For every dollar spent in surplus reserves discovered prior to 1938 the oil industry has actually expended $4.60 in replacement costs. (Details are presented in Table 8.)



Replacement Costs

Of particular significance to the oil industry at this time is a study of the cost of replacing reserves withdrawn from the underground reservoir in excess of discoveries needed to meet crude oil requirements. Facts revealed by this study, which are presented in Fig. 5 and detailed in Table 8, show that the cost of replacing deficient discoveries since 1938 has already accumulated to a total of $1,209,383,000. Last year alone, there was a deficiency between productive requirements and new oil discoveries of 1,088,000,000 bbl. At an average finding cost last year of 49.1 cents per bbl. the cost of replacing this deficiency would have amounted to a total of $534,208,000. As surplus discoveries

between 1935 and 1939 represented a total finding cost of oil in place amounting to $263,634,000, it is apparent that replacement costs over the last five years have been in the ratio of $4.60 for each dollar of cost represented by surplus discoveries made prior to 1939.

These facts have a minimizing effect upon reported profits of the oil industry. They make it evident that the oil industry is actually in a liquidating position and unless there is an early reversal in the trend of new oil discoveries, cumulative replacement costs will not long permit it to operate at a profit.

Fig. 6 shows the extent to which the ratio of new oil discoveries to production has diminished during the last nine years and the increasing number of dry holes drilled per million barrels of new oil discovered. The alarming fact is that the nation's back-log of proved reserves, which is so vital to the maintenance of immediate and future war production schedules, is being depleted to a greater degree each year. Data presented in Table 9 show that the peak reserve figure was attained on January 1, 1939, when it amounted to 22,175,000,000 bbl. Since then deficient discoveries have resulted in withdrawals aggregating 3,605,000,000 bbl.

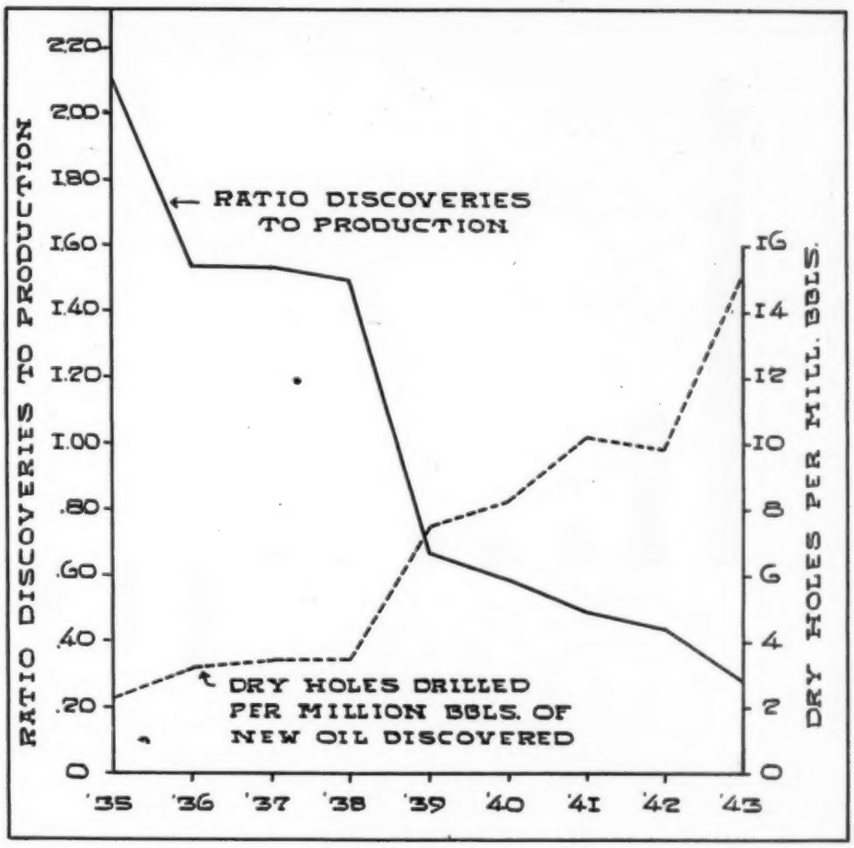


Fig. 6. Trend of new oil discoveries and number of dry holes drilled per million barrels of new reserves found. ***Discoveries are dwindling to the point where it takes the drilling of 15 dry holes before a million barrels of new oil is found.*** (Details are presented in Table 9.)

TABLE 9

Petroleum reserves and new discoveries
Years 1935 through 1943

Year	Estimated reserves Jan. 1 (million)	New reserves discovered† (million)	Crude production (million)	Ratio discovered to production	Dry holes drilled	New discoveries per D. H. (bbl.)	Dry holes per million discovered
1935	19,189	2,100	997	2.106	4,911	428,000	2.34
1936	20,292	1,700	1,100	1.545	5,296	321,000	3.12
1937	20,892	1,975	1,279	1.544	6,420	308,000	3.25
1938	21,588	1,800	1,213	1.484	6,043	298,000	3.36
1939	22,175	850	1,265	.672	6,357	134,000	7.48
1940	21,760	800	1,353	.591	6,617	121,000	8.27
1941	21,207	680	1,402	.485	6,885	99,000	10.12
1942	20,485	560	1,387	.404	5,532	101,000	9.88
1943 (p)	19,658	420	1,508	.280	6,273	67,000	14.94
1944 (p)	18,570	- ?	1,625*	?	?	?	?

†Extensions and revisions credited to years of original discovery.
(p) Preliminary—subject to final revision.
*Projected for year 1944.

	1935-38	1939-43
New reserves discovered	7,575,000,000	3,310,000,000
Crude oil produced	4,589,000,000	6,9 5,000,000
Surplus	2,986,000,000	
Shortage		3,605,000,000
Ratio discoveries to production	1.65	.48

TABLE 10

Crude oil production of leading states
(In thousands of barrels)

State	1943 (p)		1942		Per cent change
	Total	Daily	Total	Daily	
Texas	593,835	1627	483,097	1324	+23
Oklahoma	123,265	338	140,690	385	—13
Kansas	105,728	290	97,636	267	+ 9
Louisiana	122,984	337	115,785	317	+ 6
Arkansas	27,494	75	26,628	73	+ 1
New Mexico	38,750	106	31,544	86	+20
California	283,580	777	248,326	680	+15
Mississippi	19,094	52	28,833	79	—34
Illinois	82,144	225	106,391	291	—23
Other states	111,432	305	107,715	295	+ 3
Total U. S.	1,508,306	4132	1,386,645	3799	+ 9

(p) Preliminary—subject to final revision.

Oil Reserve Situation

The following data sum up the reserve picture between January 1, 1935 and January 1, 1944:

Estimated reserves, January 1, 1935	19,189,000,000*
Reserves discovered, 1935 through 1943	10,885,000,000
Total to account for	30,074,000,000
Crude oil produced, 1935 through 1943	11,504,000,000
Estimated reserves, January 1, 1944	18,570,000,000

*Revised to include extensions and revisions of original discoveries.

Declining Reserve Ratio

Another important angle on the U. S. oil reserve situation is the realization that the ratio of total reserves to annual oil production has declined from 19.1 in 1935 to 11.4 in 1944. The latter figure is based upon revised estimates for the beginning of this year and projecting productive requirements for 1944 at 1,625,000,000 bbl. It is difficult to determine what the proper ratio should be to maintain production schedules of the nation within efficient limits. It is obvious, however, that a ratio of 11.4 is

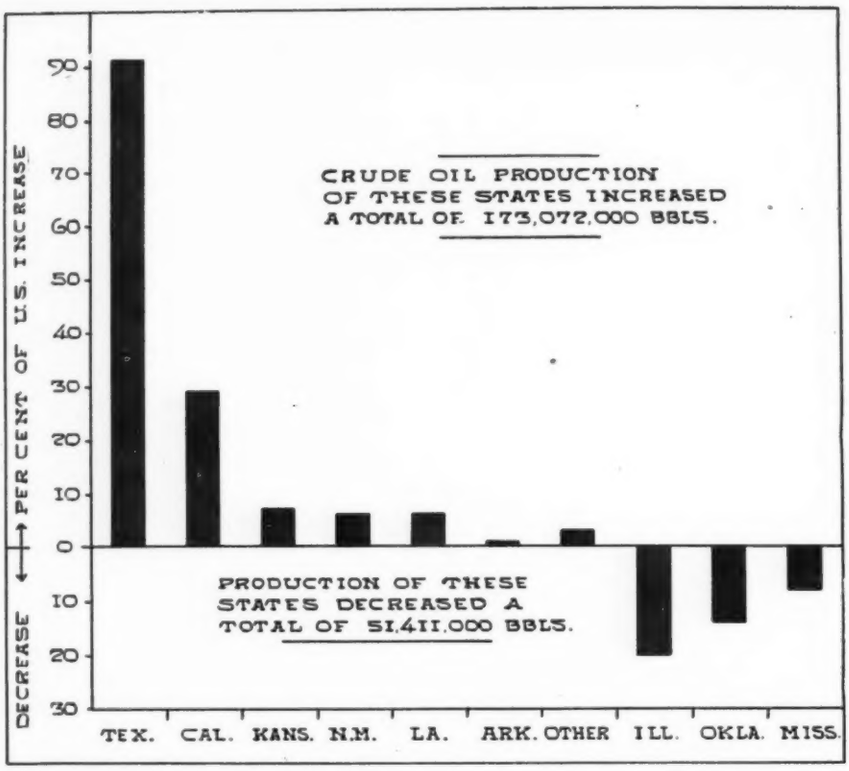


Fig. 7. Sources of increased crude oil production in 1943. Texas contributed 91 per cent of the net increase in crude oil production of the United States during the past year. Texas and California supplied 84 per cent of the gross gains in production last year. (Details are presented in Table 10.)

TABLE 11
Wildcat drilling activity in 1943*

State	Oil	Gas	Dry	Total	Per cent dry
Texas	130	16	1014	1160	87.4
Oklahoma	46	19	262	327	80.1
Kansas	58	1	395	454	87.0
Louisiana	33	6	106	145	73.1
Arkansas	2	0	65	67	97.0
New Mexico	7	2	30	39	76.9
Illinois	83	3	434	520	83.5
California	8	9	150	167	89.8
Other states	254	24	732	1010	72.5
U. S. total	538	78	2753	3369	81.7
Year 1942	591	61	2598	3250	80.0

*Preliminary—subject to final revision.

TABLE 12
Drilling statistics—1942-43

		Oil	Gas	Dry	Total	Per cent dry
Texas	1943	2,442	129	1,864	4,435	42.0
	1942	3,041	186	1,461	4,688	31.2
Per cent change		−19.7	−30.6	+27.6	−5.4	+10.8
Louisiana	1943	340	77	283	700	40.4
	1942	558	26	295	879	33.6
Per cent change		−39.1	+196.1	−4.1	−20.4	+ 6.8
Oklahoma	1943	555	88	558	1,201	46.5
	1942	524	86	549	1,159	47.4
Per cent change		+5.9	+2.3	+1.6	+3.6	− 0.9
Kansas	1943	873	24	805	1,702	47.3
	1942	815	80	624	1,519	41.1
Per cent change		+7.1	−70.0	+29.0	+12.0	+ 6.2
California	1943	1,175	28	326	1,529	21.3
	1942	556	25	247	828	29.8
Per cent change		+111.3	+12.0	+32.0	+84.7	− 8.5
Illinois	1943	1,096	3	792	1,891	41.9
	1942	1,124	13	797	1,934	41.2
Per cent change		−2.5	−76.9	−0.6	−2.2	+ 0.7
Arkansas	1943	144	6	131	281	46.6
	1942	103	7	74	184	40.2
Per cent change		+39.8	−14.3	+77.0	+52.7	+ 6.4
New Mex.	1943	168	8	60	236	25.4
	1942	251	12	83	346	24.0
Per cent change		−33.1	−33.3	−27.7	−31.8	+ 1.4
Others	1943	3,018	1,494	1,454	5,966	24.4
	1942	3,551	1,654	1,408	6,613	21.3
Per cent change		−15.0	−9.7	+3.3	−9.8	+ 3.1
U. S.	1943	9,811	1,857	6,273	17,941	35.0
	1942	10,523	2,089	5,538	18,150	30.5
Per cent change		−6.8	−11.1	+13.3	−11.5	+ 4.5

Note: 1943 figures are preliminary—subject to final revision.

grossly inadequate under existing war conditions. If the ratio should be, say, 15 bbl. of reserves to each barrel of efficient production, the proved reserve total should have amounted to about 24,000,000,000 bbl. at the beginning of this year instead of 18,570,000,000 bbl.

In this connection, too much emphasis cannot be placed upon the frequent misinterpretation of these ratios. The fact that the industry now has 11 times as much reserve as is annually produced, does not mean that the reserve represents an 11 years' supply that can be produced in equal amounts each year until all the reserve has been exhausted. Every oil well is a declining asset from the day it is brought into production and many of the nation's wells producing oil today will still be producing 30 years from now, but at a constantly declining rate. For this reason, it is necessary for the oil industry to maintain a reserve to production ratio that is adequate to maintain the combined crude oil production of the nation at an efficient as well as a sufficient rate.

During the period of surplus discoveries, 1935-38, the ratio of discoveries to production was 1.65. Within the next five years, including 1943, however, the ratio of discoveries to production dropped to 0.48, and in the year 1943 new oil discoveries constituted only 28 per cent of productive requirements. The effect of deficient discoveries upon replacement costs is readily appreciated when it is realized that it took the drilling of nearly 15 dry holes last year to lead to the discovery of a million barrels of new oil supply, whereas back in 1935 a million barrels of new oil were found for each 2.34 dry holes drilled by the industry.

Similarly, the measure of success attained in exploration activities may be gauged by the number of barrels of oil found per dry hole drilled. In 1935, the industry discovered an average of 428,000 bbl. of new oil for each dry hole drilled, whereas last year only 67,000 bbl. of new oil was found for each dry hole. Thus, the chances of finding new production were six times as successful in 1935 as they are today. Dry holes, of course, do not result in oil discoveries, but they serve as a reliable index of the oil industry's exploratory efforts.

Gain in Production

Crude oil production of the United States increased more than 121,000,000 bbl. last year, which amounted to an in-

crease of 333,000 bbl. daily. Texas contributed 91 per cent of the net production gain of the nation last year, which brought the state's output up to more than 593,000,000 bbl. This was an increase of more than 110,000,000 bbl. over 1942 and constituted a gain in daily output of 303,000 bbl. States that reported increased output last year showed a combined production gain of over 173,000,000 bbl. Of this gross gain, Texas and California supplied 84 per cent. Oklahoma, Mississippi, and Illinois reported decreased production that combined to a total of more than 51,000,000 bbl. These changes are graphically shown in Fig. 7 and the detailed statistics for the leading states are presented in Table 10.

West Texas oil fields reported substantial increases in oil production last year. Cowden, Foster, Goldsmith, McElroy, Slaughter-Duggan, Wasson, and Yates showed combined gains of 159,000 bbl. daily. Output of the Van pool, in East Central Texas, was up 17,000 bbl. daily; East Texas production increased 5,700 bbl. daily; Tom O'Connor, in Southwest Texas, reported 14,000 bbl. increase. Coastal Texas fields of Anahuac, Conroe, Hastings, and Thompsons reported combined gains of 73,000 bbl. daily.

The Oklahoma City field and St. Louis-Pearson area recorded a combined decrease in production last year of 17,000 bbl. daily. Tinsley field, Mississippi, reported a loss in production last year of 16,000 bbl. daily. The Louden and Salem pools, in Illinois, showed a combined production loss of 12,000 bbl. daily. Reed City field, Michigan, also reported a decline in output of 7,000 bbl. daily. In New Mexico, the Eunice, Hobbs, Monument, and Vacuum pools reported combined increases in production of nearly 16,000 bbl. daily. Practically all the increased production reported by California came from the heavy oil areas of the San Joaquin Valley.

Production Inefficient

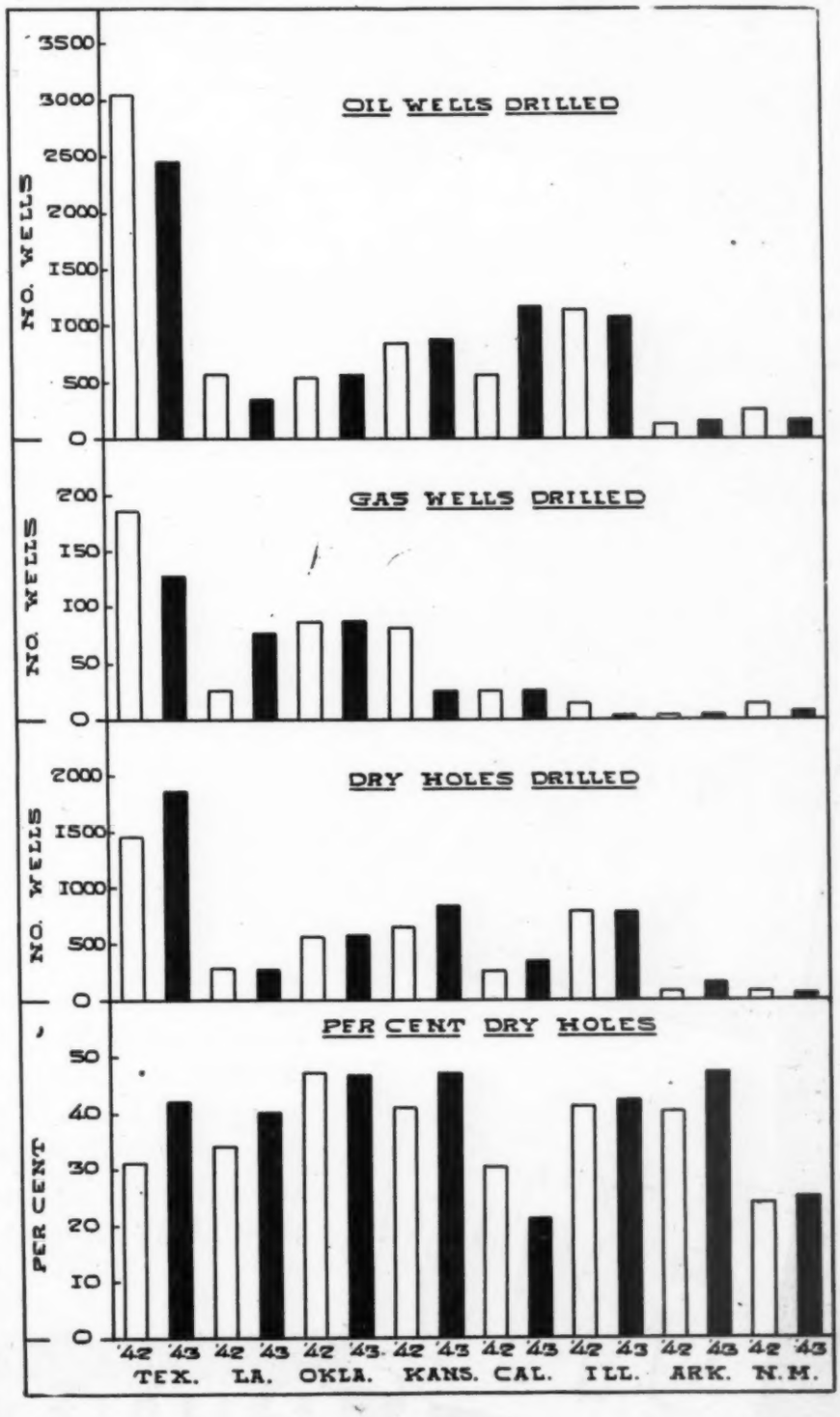
A majority of the oil producing states are reported to be producing oil in excess of efficient rates and the prospect of a further, necessary increase in crude oil production in 1944 of more than 300,000 bbl. a day is likely to prove detrimental to many of the nation's important oil fields. Figures released from time to time by various engineering committees indicate that the maximum efficient production rate of existing oil producing facilities of the nation is about 4,300,000 bbl. a day. Yet, with discovery results continuing to show greater losses each year it is probable that the efficient production rate of the nation will have to be revised downward to a total of about 4,275,000 bbl. in 1944. Against this, the industry will be obliged to provide a production of from 4,450,000 to 4,500,000 bbl. of crude oil daily. In the face of this situation the industry is not only confronted with a deficiency in new reserve discoveries, but with the prospect of a deficiency in efficient productive capacity as well.

More Wildcats

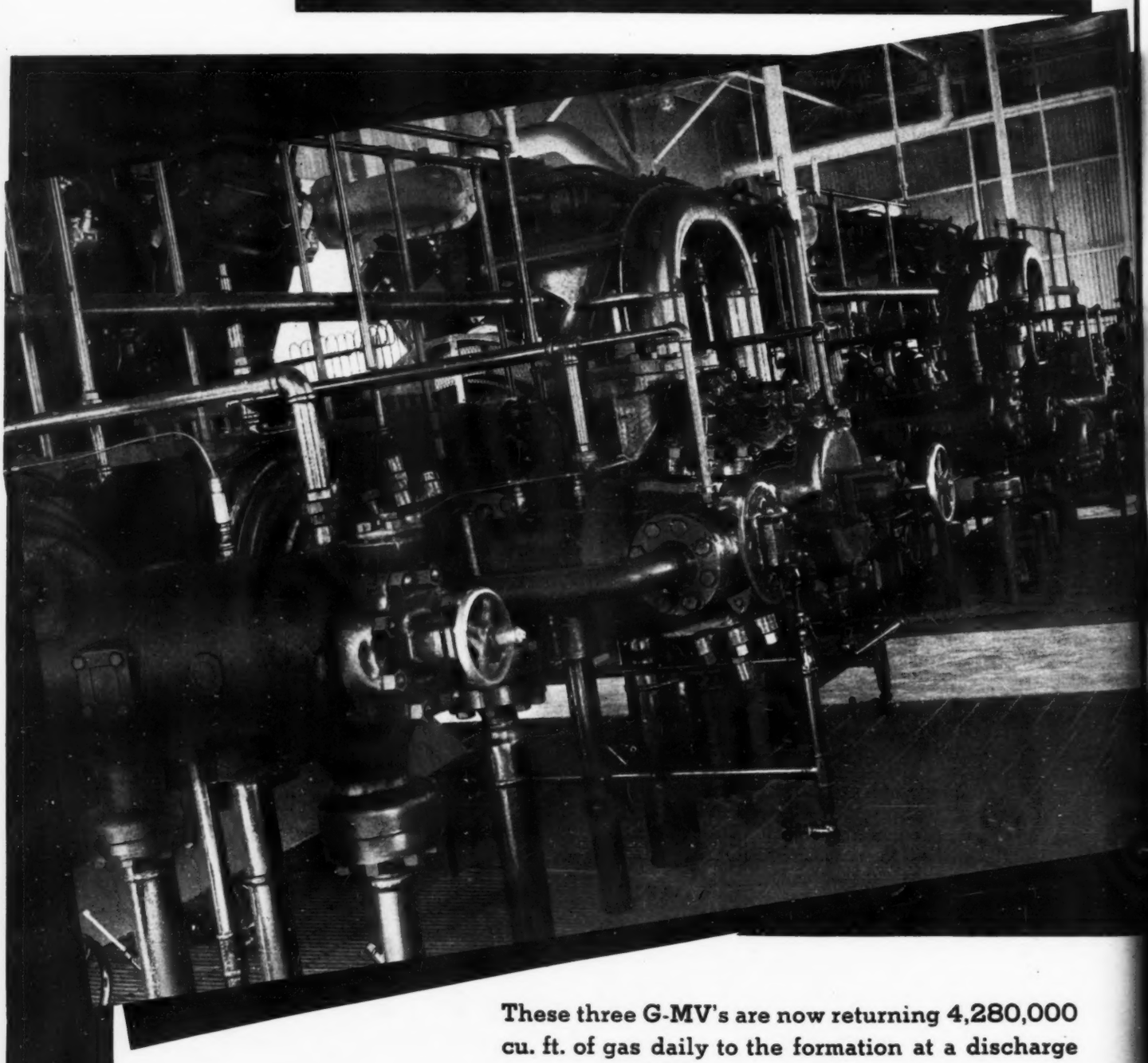
Preliminary figures of wildcat drilling for 1943 indicate that about 3369 wildcats were drilled, which was an increase over 1942 of about 119 tests. These exploratory operations resulted in the completion of 538 oil wells and 78 gas wells, which was a decline in productive wells of about 36. Wildcat dry holes increased from 2598 in 1942 to 2753 in 1943, whereas the dry hole ratio

(Continued on Page 74)

Fig. 8. Comparative field operations for 1942 and 1943. Fewer new oil well completions and a further increase in dry hole ratios were experienced during the past year. (Details are presented in Table 12.)



...PRESSURE



These three G-MV's are now returning 4,280,000 cu. ft. of gas daily to the formation at a discharge pressure of 1825 p. s. i. Each unit has a rated capacity of 2,000,000 cu. ft. a day at 50-lb. suction and 2,500-lb. discharge pressure. Photo above shows close-up of low pressure cylinder; at left, high pressure.

TYPE G-MV ANGLE

Compressors

New York Washington Bradford, Pa. Parkersburg, W. Va. San Francisco, Cal. Seattle, Wash.

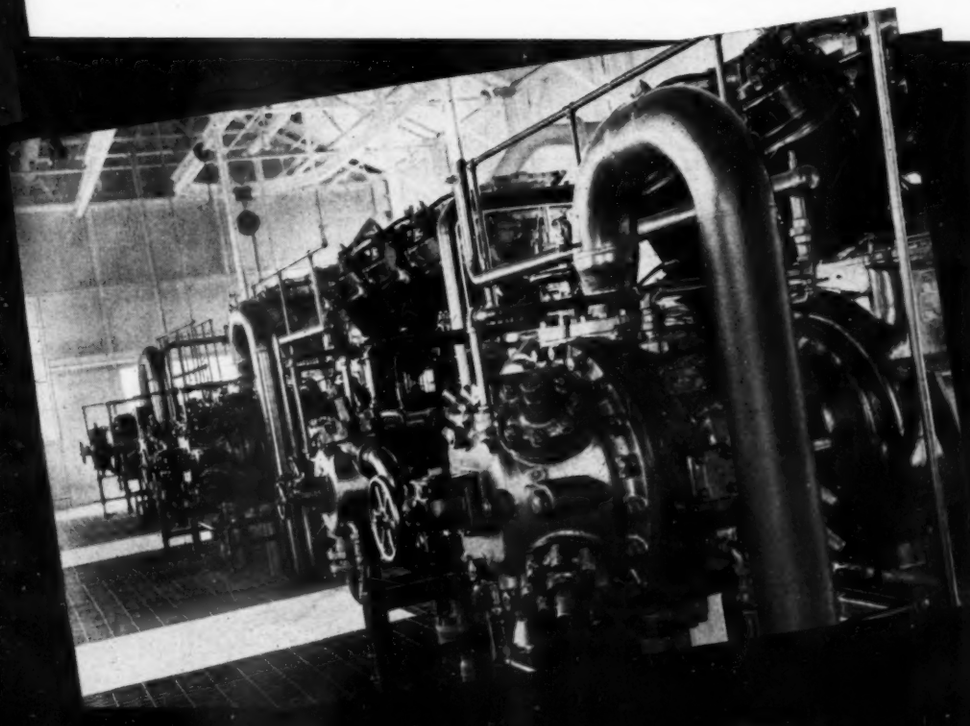
MAINTENANCE at the WERTZ DOME

THREE Cooper-Bessemer G-MV compressors are used in pressure maintenance operations at the Wertz dome field of Sinclair Wyoming Oil Company, and after two and a half years of operation are credited with 1,623,237 barrels of oil which could not otherwise have been produced in that period.

Previously it was estimated that fluid withdrawal could not exceed 3300 barrels daily without depletion of reservoir pressure. Under the gas injection program sustained withdrawal has been 5750 barrels daily, and in addition, the reservoir pressure has been increased sixteen p. s. i.

While originally much concern was felt about corrosion from H2S, the system was installed with special precautions to prevent the formation of sulphuric acid, and to date the plant has shown no sign of corrosion.

The compressors are 600 horsepower, two cycle, V-angle, gas engine compressors. Sinclair is finding them ideal, for this pressure maintenance program. Cooper-Bessemer G-MV's are built to give economical, long-lived service wherever compressors are needed in the oil and gas industries.



G-MV's are on the job—

Continuous gas injection for 2½ years without a sign of H2S corrosion.

by **Cooper-Bessemer**

MOUNT VERNON, OHIO AND GROVE CITY, PENNA.

Houston, Dallas, Greggton, Pampa and Odessa, Texas Tulsa Shreveport St. Louis Los Angeles

(Continued from Page 71)

increased 1.7 per cent to an average of 81.7 per cent. (See Table 11.)

Arkansas showed the highest dry hole ratio in wildcat drilling last year, with 97 per cent dry holes. California, Texas, and Kansas showed dry hole ratios of 89.8, 87.4 and 87.0, respectively.

Among the most important new discoveries made last year were the Ellenberger discovery in Winkler County, Texas; the Vincent field in Howard County, Texas; the Union field in Andrews County, Texas; the Russell field in Gaines County, Texas; an Arbuckle lime horizon in Rice and Stafford Counties, Kansas; the Studley field, Kansas; the Simpson Ordovician in Pratt County, Kansas, and a semi-major discovery in Arkansas, the West Atlanta field. The year's most important extension discovery was made in the Ten Sleep in the Elk Basin area of Wyoming. This is rated for about 125,000,000 bbl. of additional reserves.

All told, wildcatting results in 1943 added 271 new fields, 130 new pay formations, and about 137 extensions to previously discovered areas. First estimates of new oil discoveries for the year aggregated about 245,000,000 bbl., whereas extensions to previously discovered fields contributed about 535,000,000 bbl. of additional reserves.

All field operations in the United States last year, based upon U. S. Bureau of Mines data for the first ten months of the year and projected for the remainder of the year, indicated a total of 17,941 wells drilled compared with 18,150 in 1942. The dry hole ratio last year rose to 35 per cent from 30.5 per cent in 1942. Fig. 8 shows graphically the changes recorded in well drilling last year in comparison with the results of the preceding year. Detailed figures and changes recorded by the leading oil states are shown in Table 12.

California Price Boost

California reported an increase in well completions last year of nearly 85 per cent, whereas the number of producing oil wells completed in that state showed a gain of 111 per cent. This marks an outstanding example of what may be accomplished in the way of increased drilling activity in response to an advance in the price of crude oil. On March 25, 1943, in response to the need for increased production of heavy crude oil, the price of California crude of 25 gravity and below was advanced 25 cents per bbl. On April 12, 1943, higher prices were permitted for lighter gravities if the posted price fell below the adjusted ceilings. The results that followed speak for themselves; drilling activity was greatly accelerated and concentration of effort on proved and semi-proved areas brought about a better than average degree of success and a corresponding reduction in the dry hole ratio of 8½ per cent.

Fewer new wells were drilled in Texas last year, the total of all wells completed showing a decline under 1942 of 5.4 per cent. Drilling results in Texas were apparently less successful, as the dry hole ratio rose to 42 per cent from 31.2 per cent in 1942. Louisiana, Illinois, and New Mexico also recorded reduced drilling activity last year and increases in dry hole ratios. Oklahoma, Kansas, California, and Arkansas showed greater drilling activity last year than in 1942. Arkansas operators drilled 281 wells last year, which represented an increase over 1942 of approximately 53 per cent. The dry hole ratio, however, rose to 46.6 per cent from 40.2 per cent in 1942. This was due primarily to decidedly unfavorable wildcatting results, which showed 65 dry holes drilled out of 67 wildcat tests drilled in that state last year.

More Wells Drilling

A check of new drilling operations in the United States at the close of 1942 indicated a total of 2969 new well operations in progress, as compared with 2313 wells drilling at the close of 1942. The increase of 656 new operations this year over last year is highly encouraging in the light of the unfavorable exploratory results of last year. The upturn in new drilling operations may be due to a number of reasons, including the realization that more drilling is imperative to arrest the alarming deficiency in new reserve discoveries. It is likely, however, that many of these new wells have been started under the conviction and hope that the long overdue crude oil price advance may be realized this year.

Oklahoma and Kansas reported a material increase in new drilling operations over a year ago. The combined increase for these two states is 229 wells, an increase over 1942 of 56 per cent. California, in continued response to last year's crude price advance, reported an increase in new drilling operations of 96 wells, which represents an increase over 1942 of nearly 78 per cent. New Mexico and Illinois reported decreased new drilling activity, showing a combined slump in new operations of 97 wells or a decrease under 1942 of 25 per cent. (See Table 13.) ——☆☆☆

Fig. 9. Status of new drilling operations of leading states—1942 and 1943. ***The upturn in new drilling operations at the close of 1943 is double-barreled; an urgent need for new reserves and the undying hope of oil operators for higher crude prices.*** (Details in Table 13.)

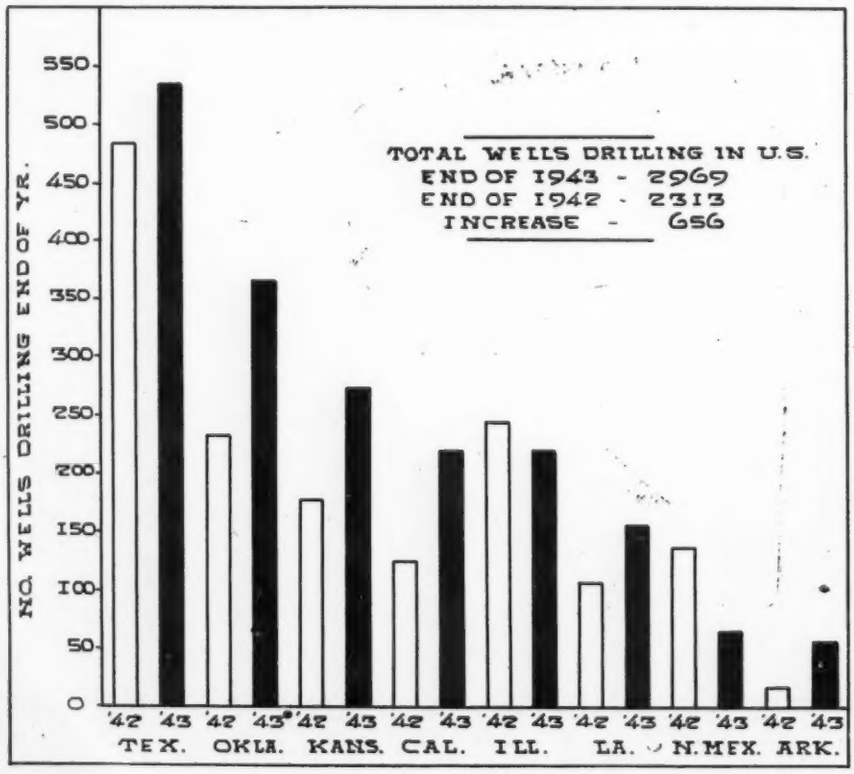


TABLE 13

Number of wells drilling
Close of 1942 and 1943

State	Dec. 31, 1943 (p)	Dec. 31, 1942	Change
Texas	535	483	+ 52
Oklahoma	365	231	+134
Louisiana	155	107	+ 48
Arkansas	57	17	+ 40
California	220	124	+ 96
New Mexico	65	138	— 73
Kansas	272	177	+ 95
Illinois	220	244	— 24
Other states	1080	792	+288
Totals	2969	2313	+656

(p) Preliminary—subject to final revision.

Super Shrink-Grip

The NEW Standard of the Industry!

Save

- TRANSPORTATION COSTS
- RIG SHUT-DOWN TIME
- MACHINE 'BUCKING-ON' COSTS

The Reed Super Shrink-Grip Tool Joint incorporates all of the safety advantages of the Reed Shrink-Grip Tool Joint, but has in addition, a gauging shoulder inside the tool joint which affords an added seal and protection against leakage and failure.

These safety features will give greater service life to your drilling string and, as they may be applied or replaced at the rig, will save shut-down time, long hauls and excessive transportation costs.

BUY WAR BONDS

BIT COMPANY

EXPORT OFFICE:
1836 R. C. A. BUILDING
NEW YORK 20 U. S. A.

Drilling Program in California

PETROLEUM ENGINEER Exclusive Feature

☆ Minimum of 1704 new wells scheduled for 1944

by Wallace A. Sawdon

Pacific Coast and Foreign Editor

OIL will be an important factor in an accelerated Pacific war and the necessary supply of refined petroleum products on the Pacific Coast must be maintained. California's present crude oil production capacity is not quite adequate to meet the contemplated combined military and civilian requirements where even the civilian use of petroleum products is to a great extent utilized, both directly and indirectly, in the war effort. Various means are being taken to maintain the supply during 1944 and these include shipments by tank cars that have already begun coming into the state and proposed plans for secondary recovery in various fields that may or may not be carried out. The drilling of new wells, however, is of prime importance in increasing the production of California and the drilling program for the coming year has therefore been expanded to help meet the situation.

The minimum number of new wells actually scheduled by the operators as of January 1 for each quarter of the year 1944 is given in Table I. This schedule, with a total of 1704 wells for the year, is rather conservative. It will be noted that the number of wells to be drilled for field development decreases with each quarter. This is a natural precaution of the operators who do not wish to plan more than 90 days in advance because of too many uncertain factors. The number of wildcats is more of a guess than an estimate and favorable circumstances may increase the number of wildcats considerably. Wildcat drilling is now up approximately 15 per cent above what it was a year ago and the major companies show a tendency toward a further increase that may reach to more than 30 per cent. It is hoped that the total number of wells to be drilled in California during the year will be at least 2060 and expectations of some operators are that the number will exceed that by several hundred.

Factors in Program

Several factors have to be given consideration in contemplating increased drilling programs. Fortunately, most adverse conditions show signs of being alleviated. Foremost is the materials situation, which has already been relieved to some extent and which, because of the realization of the importance of greater production on the Pacific Coast, will probably be further eased. This does not mean, of course, that all the materials operators want are going to be made as readily available as in pre-war years, but there does appear to be a probability that any materials whose use will make sufficient oil available to warrant their expenditure will be provided.

Shortage of manpower has limited drilling activities during the past year. It will probably have an effect on the number of wells completed during the coming year although there appear to be better prospects of some experienced men being returned to the oil industry. To what extent this manpower situation will be improved cannot be foretold and it remains a factor in the rate of development. Eyperience is probably a greater factor in wildcat than in field extension drilling.

Another phase of the manpower situation is housing. This has been particularly adverse in some of the coastal areas where living quarters have sometimes not been available for crews that could otherwise be put to work. In field development work, however, the transference of crews from field to field may not have been given full consideration and the number of wells completed can possibly be increased by proper transfer of crews.

The price of crude oil will have an effect on drilling, particularly in wildcat operations. This subject is so familiar to all that no discussion is necessary. What the outcome will be is anyone's guess.

Another matter for consideration is the manufacture of equipment for drilling the greater number of wells. Virtually all manufacturers of oil well equipment have been doing war work and it is now necessary to devote more effort to making oil equipment. There is still an uncertainty in this situation that may result in a time lag in the manufacture of necessary equipment, especially in certain types of equipment.

Depths and other conditions will influence the types of rigs that will be employed in drilling. During the past year

TABLE I

Estimated minimum number of wells scheduled in California for 1944

	1st quarter	2nd quarter	3rd quarter	4th quarter
Field development				
San Joaquin Valley	261	221	172	168
Los Angeles Basin	92	81	65	48
Coastal Area	57	57	51	51
Total	410	359	288	267
Dry holes in field development (semi-wildcat, flank, etc.)	20	20	20	20
Wildcats	60	60	60	60
Gas wells	10	10	10	10
Condensate wells	5	5	5	5
Total per quarter	505	454	383	362

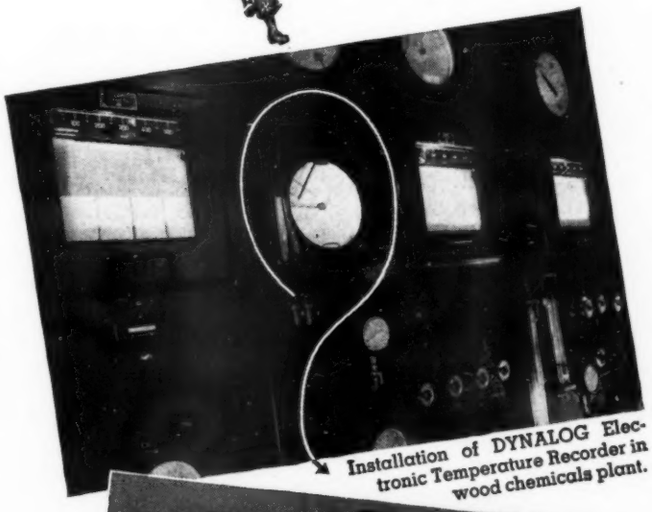
Total minimum number of wells scheduled for year—1704.

Estimated average depths

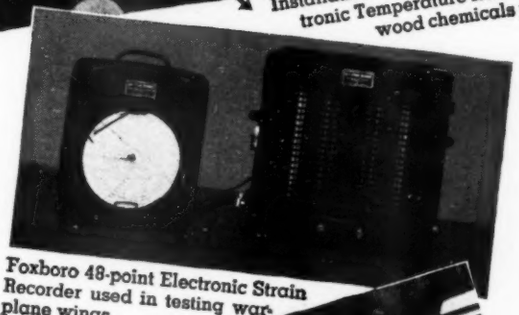
San Joaquin Valley	Los Angeles Basin	Coastal Area
3200 ft.	4000 ft.	6000-6500 ft.

Let's Get Down to Earth

ON ELECTRONIC PROCESS INSTRUMENTS!



Installation of DYNALOG Electronic Temperature Recorder in wood chemicals plant.



Foxboro 48-point Electronic Strain Recorder used in testing warplane wings.

Verigraph Electronic Recorders widely used in paper and rubber industries.

No "revolution" likely... but Foxboro progress points to important specialized advances

There's little likelihood that electronic instruments will soon replace all of today's standard industrial instruments. The majority of processes require no radical improvements in instrumentation. Yet, Foxboro's pioneering research already has demonstrated how electronic sensitivity can importantly increase the usefulness of instruments for some applications ... and make possible *the first practical instrumentation ever available* for others!

For example, rubber and paper industries have used Foxboro's Verigraph Electronic Recorders for many years, to obtain weight-and-moisture measurements never before available. In wartime chemical production, Foxboro Electronic Temperature Recorders now furnish records that can be read to 1/10°C. And in leading warplane plants, other Foxboro Electronic Instruments enable exact readings of wing strains at 48 test-points, almost simultaneously!

Today's production of these instruments is focused on war applications. Tomorrow, these and other measurement-and-control advances will be available to all industry, in Foxboro's new DYNALOG Electronic Instruments! **The Foxboro Company, 130 Neponset Ave., Foxboro, Mass., U. S. A.**

DYNALOG measurement and control by FOXBORO

REG. U. S. PAT. OFF.

a great many of the wells drilled in California have been shallow holes that, although coming in with small initials, have given immediate production. The average depths of the wells contemplated for 1944 are greater than those of the last year or two and although an accurate estimate cannot be made of depth, the expected averages for each district will be approximately as shown in Table I.

Past and Present

In evaluating the situation in California due consideration must be taken of what has happened during the two war years of 1942 and 1943. This is shown graphically in Fig. 1 by means of which a comparison can be made of these two years with the five previous years. To make the 1944 drilling program most effective in increasing production, more highly productive areas must be developed and, if possible, additional areas and additional zones of greater productivity must be discovered.

From Fig. 1 it can be seen that the average initial production began declining early in 1941 and reached a general low by the end of 1942. The number of wells completed reached a low early in 1942 but since then has increased steadily until the present time. During 1943 the increase in number of wells completed was maintained but the size of wells remained at approximately the low level reached by the end of 1942. The total initial production was, of course, increased by the greater number of wells but was far from meeting the increased demand that is also indicated by the curves in Fig. 1.

Probably the greatest factor in the conditions indicated for 1942 and 1943 was the lack of materials. A large percentage of the casing necessary for completing the increased number of shallow wells was recovered from other wells, as discussed in a previous article.[1]

The operators in California deserve credit for meeting the situation as they did and making available a considerable amount of shallow oil by their ingenuity in utilizing salvaged pipe. The other conditions mentioned as being necessary for consideration in future drilling also had their influence on operations during the last two years.

The situation in California can be changed considerably if materials are made available for drilling more wells in more highly productive areas and if the manpower can be procured to drill the wells. This assumes, moreover, that the wells drilled will be produced efficiently by modern methods that provide for maximum ultimate recovery from the reservoir. To what extent wildcat operations may be successful cannot be forecast but any discoveries of new fields will add that much to the productive capacity of the state and, as operators will locate wildcats where the prospects are brightest, the materials for their drilling will certainly be warranted.

[1] "Casing Salvage Aids Steel Conservation," by Wallace A. Sawdon, *The Petroleum Engineer*, September, 1943.

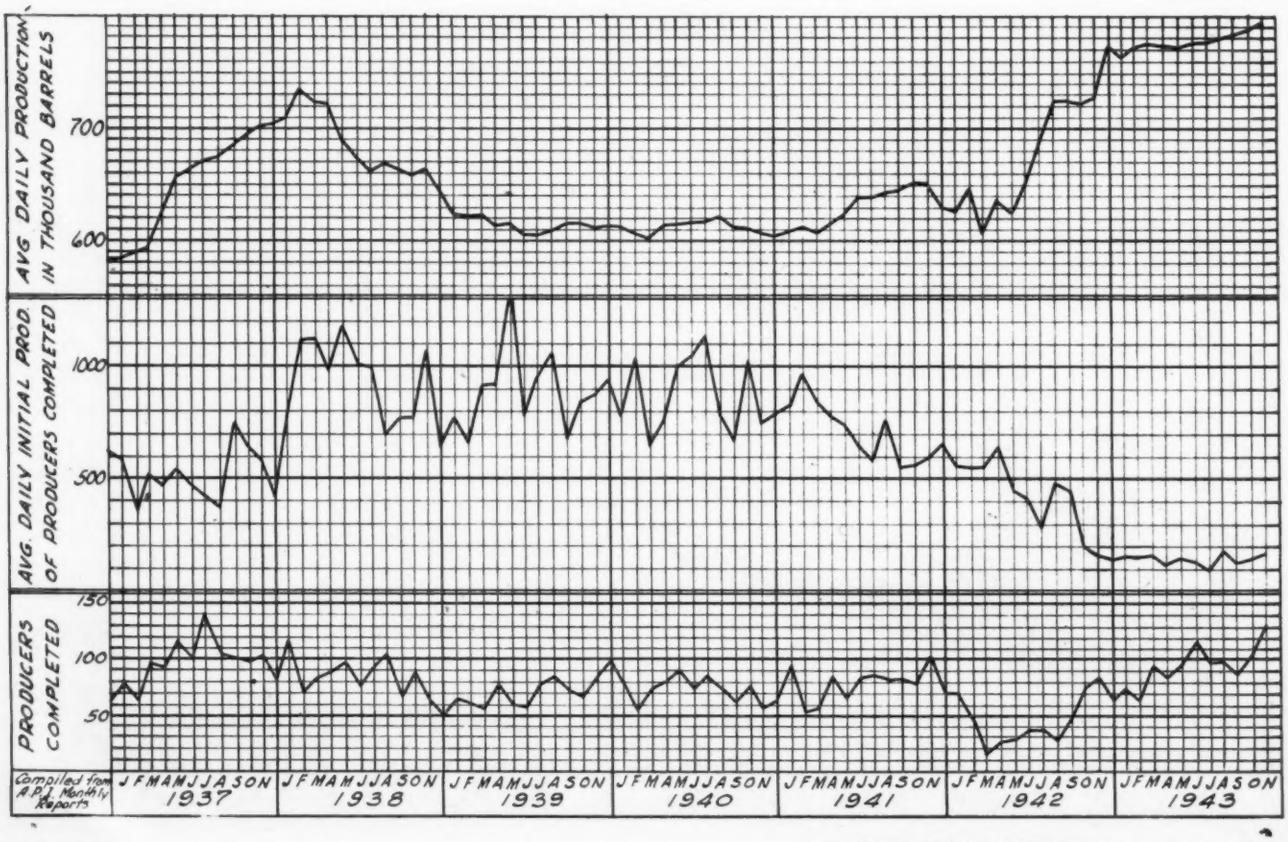
☆ ☆ ☆

Well May Win $50,000

Humble Oil and Refining Company's Florida well may qualify for the $50,000 cash reward offered by the state for the first commercial oil producer in Florida. A 30-day production test is being made to determine whether the well at Suniland has enough production.

The well has yielded an average of 77.37 bbl. of oil a day during the first week of the state-inspected test, according to the state geologist. He said the oil was separated from a mixture of fluid in which the salt water content varied from 83.7 to 88 per cent.

Fig. 1



20 Years Ago

PACIFIC TOOK THE MICROMETER

AND REVOLUTIONIZED THE OIL PUMPING INDUSTRY

With the germ of an idea and the brains to think through, Pacific engineers in a modest little pump shop, startled the world with a radically new oil pumping technique.

In those days, oil pumps were costly and unreliable, fraught with repair bills and a meager life measured in months. With questionable materials and loose tolerances, pumps either ground themselves to uselessness or corrosion did the trick.

So these alert Pacific engineers took the micrometer, fine dimensions, new alloys, the finest of materials and developed new engineering methods. With uncanny mental and mechanical skill they created a group of precision pumps that defied all oil field and refinery pumping conditions—pumps with a life measured in years instead of months. A new era of pumping efficiency and economy began. Pacific Engineered Pumps became the standard of quality and performance the world over.

TODAY—in a large modern plant—Pacific still maintains its leadership with a most complete line of centrifugal, turbine and plunger types of precision pumps for water well, oil well, refinery, pipeline, process, boiler feed and hot oil operations. Large emulsion pumps for synthetic rubber plants are also a part of the complete Pacific line.

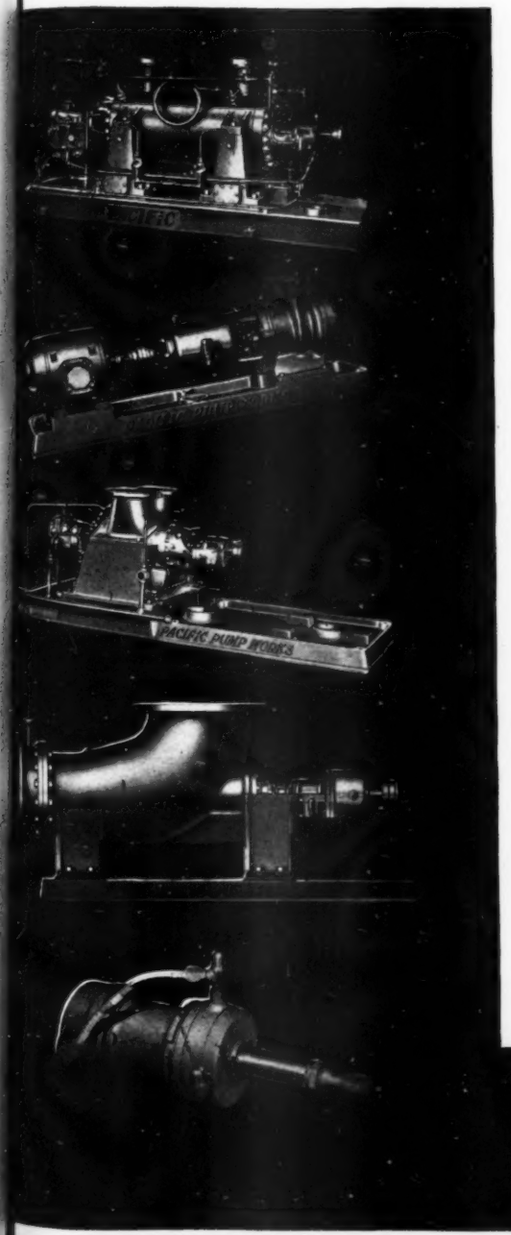
Oil company engineers everywhere know "you can't buy a better pump than PACIFIC."

DEVOTED 100% TO WAR PRODUCTION

PACIFIC PUMP WORKS

EXECUTIVE OFFICES AND PLANT: HUNTINGTON PARK, CALIFORNIA
EXPORT OFFICES: 30 ROCKEFELLER PLAZA, NEW YORK

Sales and Service Offices in principal cities in the United States
Affiliated with the Dresser Industries



PACIFIC *Engineered* PUMPS

"Swamp Buggy" Made from Salvaged Materials

PETROLEUM ENGINEER Exclusive Feature

☆ Machine equipped with balloon wheels capable of transporting load of 2000 lb.

by Don Attaway
Arkansas Natural Gas Corporation

THE critical shortage of materials and equipment has served only to whet the genius of members of the Geophysical Department of the Arkansas Natural Gas Corporation. When members of this department found urgent need for a new method of transportation in the swamps, bayous, and lagoons of South Louisiana, they discovered a complete absence of any manufacturing firm that could supply their particular needs.

The answer to their problem came from the scrap and salvage heap in the company's warehouse yard as well as from the minds and imagination of certain department members.

It must be admitted that other clever constructors have designed "swamp buggies" and such for the moving of personnel, but when it comes to transporting tools, equipment and instruments, as well as personnel, this "amphibian jeep" born of scrap metal and reclaimed parts, is the answer.

Under the supervision of R. L. McLaren, head of the Geophysical Department, the construction of this strange monster was done at the company machine shop. With the assistance of skilled machinists it began to take shape during October, 1943.

Progress was slow as design was compelled to conform to material on hand. The machine is about 23 ft. long from tip to tip and approximately 10 ft. wide. The bed measures 14 ft. and is constructed from tank iron and discarded boiler plate.

Especially interesting are the balloon wheels. These bulging parts were fabricated from 1½ in. by 1½ in. by 3/16 in. junk angle iron with ½ in. pipe for spokes. After their framework had been completed, they were covered with sheet metal. The wheel treads are covered with 14 gauge metal whereas 16 gauge metal was used for the sides. This covering made the wheel airtight so that the four wheels would float the entire chassis; however, the effect of temperature had to be taken into consideration and a ⅛ in. breather hole was left on each hub.

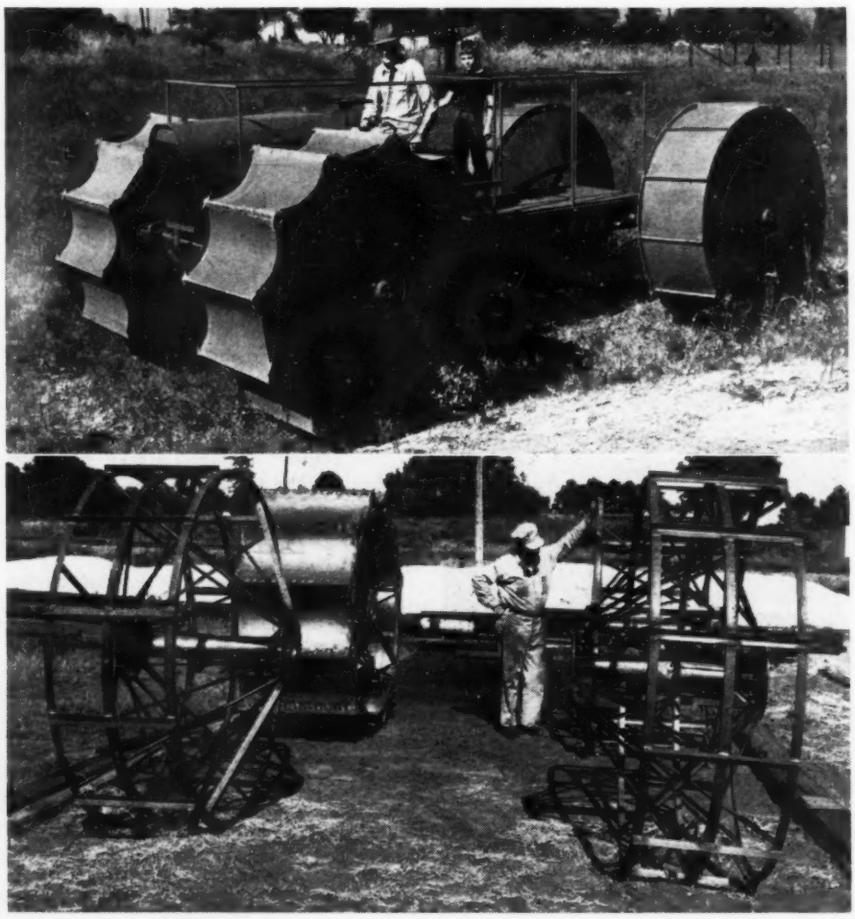
The complete wheel weighs about 890 lb. The front wheels are 6 ft. 6 in. in diameter and the rear wheels are 6 in. smaller. All wheels have a 3 ft. tread.

Motive power is provided by a rebuilt Model B Ford engine, which is attached by chain and sprocket to the front wheels. A complete differential assembly had to be fabricated from redesigned and machined steel castings. Although the driver's seat and steering wheel are forward, they really operate the rear wheels, which act as a rudder while in water and control direction while on dry land.

The completed "jeep" is capable of transporting a load of more than 2000 lb. over any and all terrain. It has been in service in South Louisiana for several weeks and, according to E. L. Caster, head of the Land and Geological Department, is performing in a satisfactory manner. —— ☆ ☆ ☆ ——

Top—View of completed machine after test run. Note difference in front and rear wheel construction.
Bottom—Appearance of "balloon" wheels during first stage of construction showing fabrication details.

(Photos by J. E. Hampson, Arkansas Natural Gas Corp.)



Dually Completed Oil and Gas Wells*

☆ First 37 dual wells drilled effect initial saving of $2,250,000 and 6700 tons of steel

by L. L. Jordan and Alec Crowell
Arkansas Oil and Gas Commission

MORE than $2,250,000 and 6700 tons of steel are the initial saving effected by the first 37 dually completed oil and gas wells in Arkansas. These dual completions, as of December 1, 1943, account for an average monthly production of 200,000 bbl. of high gravity crude oil and condensate and 2,100,000,000 cu. ft. of natural gas, all pledged to the war effort. The high gravity production is used as a diluent for waxy East Texas crude, facilitating the movement and greatly increasing the volume that can be transported by pipe line to the eastern seaboard, whereas the natural gas, after its sulphur and natural gasoline content are extracted, moves on in its entirety to war industries and military facilities. Only 37 holes were drilled to obtain 74 producing wells.

Concurrent production from two productive zones through a single well bore has only recently become mechanically acceptable. The Arkansas Oil and Gas Commission had, up until May 27, 1942, looked upon multiple-zone completion of oil and gas wells as too hazardous, conservation-wise. On the date mentioned, a hearing was held to which the public and all interested parties were invited, and the commission found that mechanical devices were available that would permit the dual completion and production of wells having more than one commercial pay section without the commingling of fluids or gas.

Upon the issuance of their order permitting dual completions, the commission made the matter elective, but provided that only two formations could be produced simultaneously, one through the tubing and the other through the annular space between the tubing and casing. They also made the completions and recompletions subject to four conditions:

1. That sufficient notice be given the director of production of the commission to enable him to notify all offset operators of a proposed dual completion into one of a multiple or separate zone.

2. That these dual completions be made in such a mechanical manner as to meet with the approval of the director of production and chief engineer of the commission.

3. That no sweet gas be produced from any formation through a dually completed well or any other well for any purpose other than as provided by the conservation law. No sweet gas of any type be permitted to escape to the air.

4. That each well dually completed be regarded as a separate and distinct well; that a permit be obtained for the dual completion as though the well were a new well; that the production be taken separately and measured separately; and that all rules, regulations, and orders governing individual oil or gas wells shall be strictly adhered to.

The commission heard evidence at its hearing on May 27, 1942, to the effect that the average cost of the average deep well in Arkansas, including casing, tubing, Christmas tree, etc., is approximately $78,100. It was recorded that a single zone completion to 8000 ft. would cost $65,600 and one to 9000 ft. would cost $76,700. Thus, by dual completion, a saving of $64,200 or 45 per cent of the cost of the two wells could be realized.

Further, the commission was advised that the total steel necessary for completion of the deep wells was approximately 200 tons, whereas for a dual completion, the figure was only 13 tons more.

From the evidence adduced at its hearing, the commission issued the order mentioned, having procured verbal agreement on its contents from the Petroleum Administration for War. Three operators proceeded to recomplete their wells in accordance with the terms of the order, but on June 11, 1942, the commission was advised by PAW that these dual wells were in violation of Conservation Order M-68. Unfortunately, a year's time lapsed before the PAW was convinced of the wisdom of the commission's order. The PAW issued its Supplementary Order No. 9 to PAO No. 11 on May 22, 1943, which is applicable to the Dorcheat-Macedonia field. Development has gone forward at a rapid rate since that time, the foregoing being mentioned only in explanation of the retarded development between May 27, 1942, and May 22, 1943.

Thirty-two of these 37 dual completions are in the Dorcheat-Macedonia field of Columbia County. This field, which is under an extensive development program, has already proved a reserve of 90,000,000 bbl. of oil and distillate and more than 400,000,000,000 cu. ft. of natural gas. There are 66 producing well bores in the field, 21 of which are located on 1160 acres and operate as a unit, whereas two are on 40-acre units and the remaining 43 are in the center of 80-acre units.

The deeper pool — Smackover limestone—which is found at a depth of approximately 8600 ft. to 8800 ft. subsea, accounts for two-thirds of the reserves mentioned, the remainder being credited to the upper productive pools—Cotton Valley sandstone—which is found from 6500 to 8200 ft. subsea.

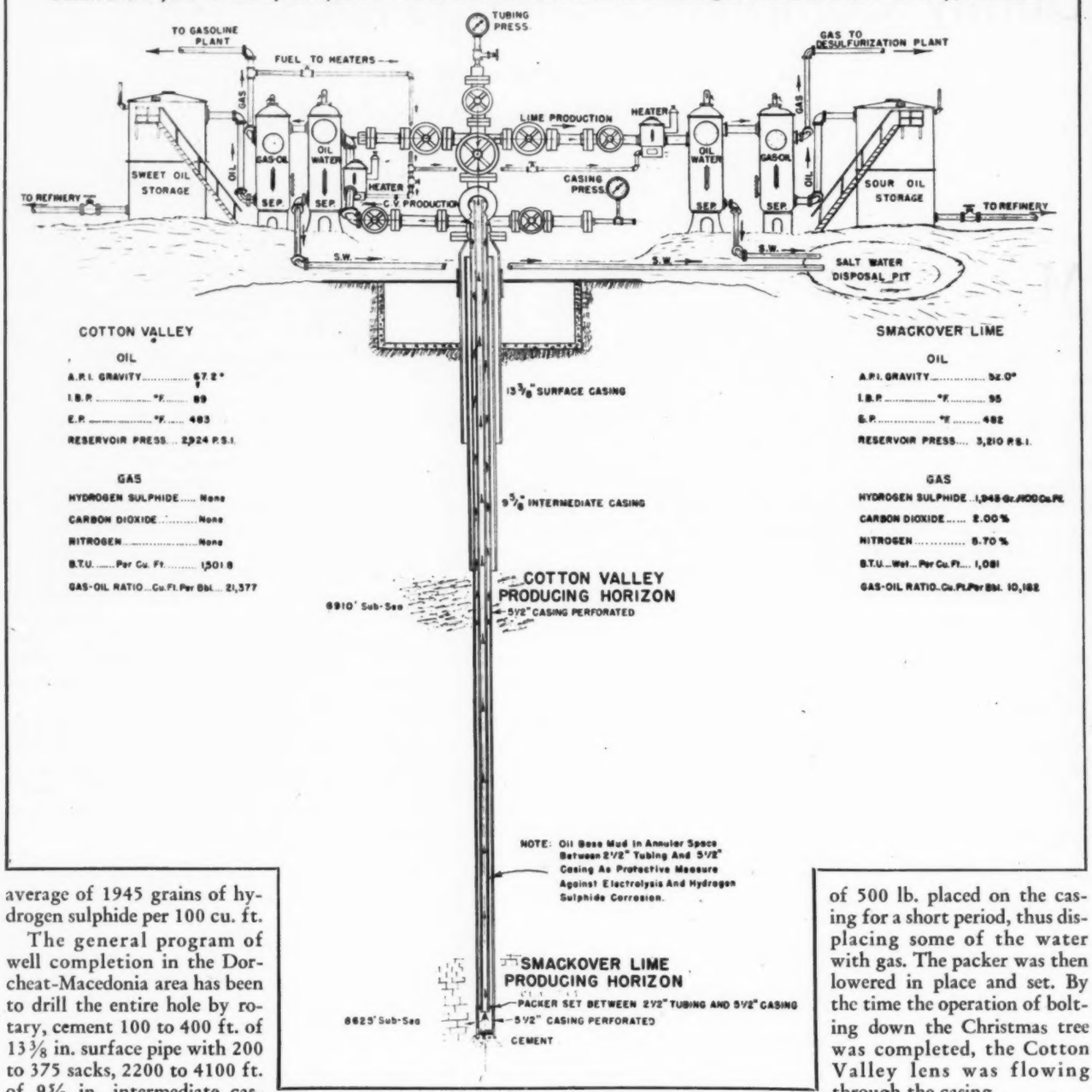
On December 1, 1943, the 66 well bores in the Dorcheat-Macedonia field represented 25 single completions in the Smackover limestone, 9 single completions in Cotton Valley sandstone lenses, 8 dual completions in two Cotton Valley sandstone lenses, and 24 dual completions in the Smackover limestone and Cotton Valley sandstone. Thus we have 66 holes drilled in this field and are getting production from 98 wells.

The upper pools in this field are numerous sandstone lenses (Cotton Valley) with reservoir pressures of from 2900 to 3600 lb. per sq. in. Some of the lenses produce water-white condensate of 60-66° A.P.I. gravity with ratios up to 20,000 cu. ft. per bbl. Other lenses produce dark 42° A.P.I. gravity oil with ratios as low as 900 cu. ft. per bbl. The gas, without exception, is free from hydrogen sulphide.

The lower pool (Smackover lime) has intercommunicating porosity throughout with a maximum interval above water of 122 ft. Although the major portion of the reservoir volume contains gas, there is a varying column of oil across the pool. A few wells are now producing from this oil section, but the majority produce a liquid ranging in color from water-white to straw of 60-66° A.P.I. gravity with ratios up to 20,000 cu. ft. per bbl. The reservoir pressure is 3210 lb. per sq. in., the temperature of the zone nearest the packer 220°F., whereas the gas contains an

*Presented under title "Dually Completed Oil and Gas Wells in Arkansas Represent Tremendous Saving" before meeting Interstate Oil Compact Commission, Wichita, Kansas, December 10, 1943.

Schematic layout of dually completed well in Dorcheat-Macedonia oil and gas fields, Columbia County, Arkansas



average of 1945 grains of hydrogen sulphide per 100 cu. ft.

The general program of well completion in the Dorcheat-Macedonia area has been to drill the entire hole by rotary, cement 100 to 400 ft. of 13 3/8 in. surface pipe with 200 to 375 sacks, 2200 to 4100 ft. of 9 5/8 in. intermediate casing with 1000 to 1800 sacks, the oil string of 5 1/2 in. casing through the producing Smackover with 1000 to 2500 sacks, and complete the tubular equipment with 2 in. tubing. Both single and double separation are in use, while the general practice is to use wooden storage tanks.

That dual completions have been successful is reflected in a brief resume of operations at a well completed more than a year ago and as yet there has been no evidence of packer leaks. This well was drilled to 8920 ft. and a 5 1/2 in. oil string of 17 lb. casing was set at 8919 ft. and cemented with 1800 sacks of cement. The plug was drilled out to 8915 ft. and a Cotton Valley lens was gun perforated from 7190 to 7200 ft. with 80 shots. A Halliburton testing tool was run and a Cotton Valley lens tested. On this initial drillstem test, with a 16/64 in. top and bottom choke, 33 bbl. of 47° A.P.I. gravity oil and 37,365 cu. ft. of sweet gas were produced.

Following this test the Smackover limestone was gun perforated from 8873 to 8895 ft. with 176 shots. A T.I.W. hook-wall packer, without circulating ports, was run in the hole on 2 3/8 in. tubing, the surface joint of the tubing being a slick joint so as to permit raising and lowering through the Gray tubinghead and still have the well under control at all times.

The mud in the well bore was displaced with clear water and a pressure of 500 lb. placed on the casing for a short period, thus displacing some of the water with gas. The packer was then lowered in place and set. By the time the operation of bolting down the Christmas tree was completed, the Cotton Valley lens was flowing through the casing.

One trip with a swab was necessary to bring in the Smackover lime production through the tubing. On the initial test the Smackover limestone produced 240 bbl. of 64° A.P.I. gravity condensate and 3,100,000 cu. ft. of gas.

Multiple-zone completion of oil and gas wells, based upon the foregoing discussion, appears to be relatively simple. This is not a fact. Of the first 16 dual completions attempted in Arkansas, half were unsuccessful in segregating production from two zones in the initial effort. However, experience now has made dual completion or dual recompletion of oil and gas wells in Arkansas as routine as any drilling and original completion operation.

—— ☆ ☆ ☆ ——

Suggest a name for our pumps—a name that will identify all the pumps we manufacture . . . something that will express in a word the marked advantages and superior qualities resulting from a long-range development program that has produced simpler, more efficient pumps.

Win a $1,000.00 War Bond!

* SERIES "E" BOND—VALUE AT MATURITY DATE, APRIL 1, 1954—$1000.

all you need do is submit a name!

For the 6 best names, the following awards will be made:

1st Prize	$1000.	Series "E" War Bond
2nd Prize	$50.	Series "E" War Bond
3rd Prize	$50.	Series "E" War Bond
4th Prize	$50.	Series "E" War Bond
5th Prize	$50.	Series "E" War Bond
6th Prize	$50.	Series "E" War Bond

CONTEST RULES

All men engaged in production and drilling are eligible (and men in the Armed Forces who were previously engaged in these branches of the oil industry).
Each contestant is limited to one entry.
All entries must be postmarked not later than March 15, 1944.
All entries must be submitted on the attached coupon.
In case of ties the name with the earliest postmark wins.
All entries become the property of Fluid Packed Pump Company and the decision of the judges will be final.

Here's the reason for the contest

In 1924 this Company was formed to manufacture the Fluid Packed Pump, a distinctive 3-tube pump with the positive Fluid Seal. Because this pump filled a definite need for meeting varying difficult conditions, it met ready acceptance. While it is still maunfactured and gives outstanding service in its particular field we have added many other types of pumps, until today we are the world's largest exclusive Oil Well Pump Manufacturer, and make a pump for every need. Since old names linger in people's minds and oil men are prone to refer to *all* of our pumps as Fluid Packed Pumps, we are taking this means of selecting a new name which will identify our complete line.

A Complete Line of Pumps to Meet Every Operating Condition

Improved Insert — The quality pump equipped with one-piece hardened and honed barrel of heavy wall thickness assures unusually long life and permits several rehone jobs. The most versatile hard metal pump available.

Groove Seal — An economically priced pump providing 4 to 8 times harder barrels than ordinary pumps. Longer production and fewer replacement parts make these hardened and honed one-piece barrel pumps today's outstanding value.

Flucup—A cup and barrel-type pump of improved construction with hardened and polished barrel. Highly satisfactory for "easy to pump" wells and also recommended for wells making high gravity oil with poor lubricating qualities.

Flu-Ring — Combines 36 to 48 composition rings on a plunger body for effective sealing. One of the most efficient types for pumping wells where water volume or lubrication-free fluid is a problem.

Fluid Packed (3-tube)—An all purpose pump especially adapted for troublesome wells. (The "fluid being pumped" acts as a sealing factor.)

Tubing Liner — This standard type pump meets the requirements of volume conditions.

FLUID PACKED PUMP CO.

MAIN PLANT: LOS NIETOS, CALIF.

HUNT BLDG., TULSA, OKLA.; 4006 NAVIGATION BLVD., HOUSTON, TEXAS; TEXAS BK. BLDG., DALLAS, TEXAS; NAT'L SUP. CO. STORES, ILLINOIS FIELDS

World's Largest Exclusive Oil Well Pump Manufacturers

OIL WELL PUMPS
906 BENDIX BLDG., LOS ANGELES 15, CALIF.

P.E.

My entry as a name that best describes your complete line of pumps is

_____

NAME _____

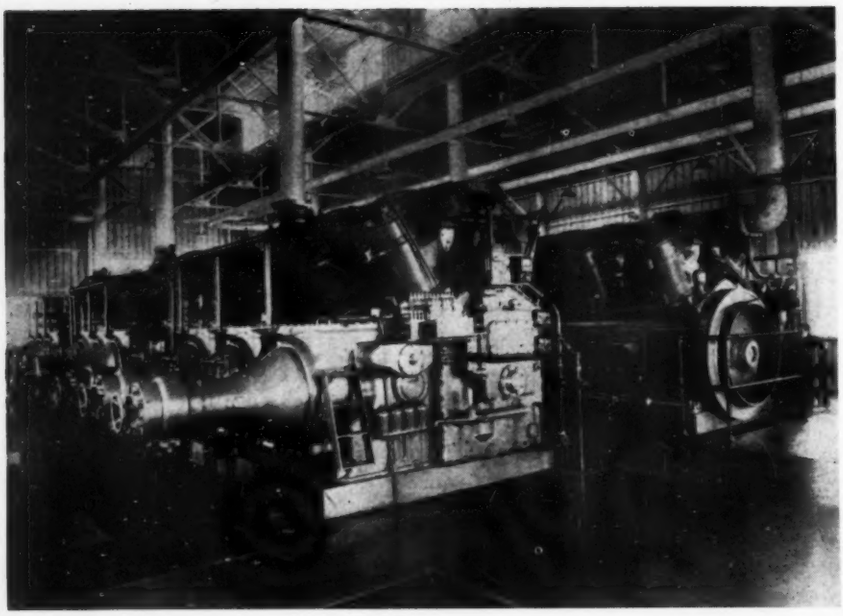
COMPANY _____

POSITION _____

ADDRESS _____

CITY and STATE _____

P 624.
P 772.3



Modern compressors such as these will give efficient service if the manufacturer's instructions are adhered to and the basic maintenance suggestions outlined in this article observed

PETROLEUM ENGINEER Exclusive Feature

Maintaining Compressors at Peak Operating Efficiency

✫ Observance of fundamental rules on care and maintenance pays dividends

by B. C. Thiel

Consulting Engineer, The Cooper-Bessemer Corporation

TODAY'S shortages in replacement parts, and wartime requirements demand that compressors be kept at peak operating capacities even when subjected to long periods of uninterrupted service. It is important that plant maintenance engineers observe certain fundamentals that apply to the care and maintenance of compressor units.

The following suggestions are summarized for the purpose of assuring the most efficient performance of large compressors regardless of the type of service they are rendering.

Lubrication

Minimum wear of moving parts can be assured by using the proper grade of lubricating oil. Too much oil, even of the best grade, eventually will gum up piston rings and cause them to stick in the grooves, thus reducing the capacity of the compressor due to piston ring leakage. Excessive wear on the cylinder walls may also result because the wire-drawing of the gases between the piston and cylinder wall will blow off the lubricating film and permit a metal-to-metal contact. The excessive oil will also collect on the discharge valves and will carbonize on the hot seats, causing the valves to leak. Insufficient lubrication obviously will cause wear on piston rings, piston and compressor cylinder.

Although there are no hard and set rules governing the lubrication of compressor cylinders, each operator should set up his own standard to apply to individual requirements, the basis of which depends upon the gas that is being compressed and the nature of the oil being used. For example, when gases containing gasoline vapor or a large percentage of the hydrocarbons are being compressed, a lubricant that is insoluble in the gas should be used. Such lubricant may be a soap solution, castor oil, or a blend of castor and petroleum oil.

It is good practice to remove a cylinder head occasionally to check the condition of the cylinder wall and make sure the cylinder is receiving the proper amount of lubrication.

Valves

All compressor valves, whether plate or poppet type, should be thoroughly overhauled so that the valves will close tightly when installed in the cylinder body. A leaking valve soon heats the valve and its surrounding area to a temperature considerably higher than the operating temperature for which the unit was designed. Excessive heat thus generated will warp the plates of the plate valves, resulting in even greater leakage or, in case of a poppet type valve, will cut and destroy the valve seat and face.

Piston Rings

Rings should be free in the ring grooves but should not have excessive play. Each ring should be fitted individually to the compressor cylinder bore so that expansion of the ring under normal heat will not butt the ends together and force the ring out against the cylinder wall to cause undue wear.

Cooling Water

Compressor cylinder jackets should be kept clean and free from scale. The water used to cool compressor cylinders should be of a composition that will pre-

When the war is over...

WE'LL BE BACK AGAIN IN CIVILIAN JOBS

The 25-year record of achievement established in the oil and gas industry qualified NO-OX-ID to go to war. In fact, the record of absolute protection against corrosion was so good that NO-OX-ID compounds and NO-OX-IDized Wrappings are being used extensively in military service.

While in the service, new records have been established in combating the corrosive influences in new and difficult wartime shipping conditions.

Along with the boys, NO-OX-ID will come home again to serve on the pipe lines of America where it has won recognition. It is the pioneer rust preventive compounded with effective rust inhibitors, together with suitable non-oxidizing basic chemicals. NO-OX-ID in some consistencies is still available for many industrial uses. Dearborn Chemical Company, Dept. L, 310 S. Michigan Ave., Chicago 4, Ill.

"THE LEADER FOR 25 YEARS"

NO'OX'ID
IRON RUST
rust preventive
NO-OX-ID-IZED WRAPPER FOR PIPE LINES

•[*For Victory, Buy United States War Bonds and Stamps*]•

vent excessive scaling in the jackets at the normal operating temperature of the compressor. All foreign matter such as mud, grit, and similar substances should be removed from the water before it is circulated through the compressor cylinder jackets. The amount of water, however, should be so regulated that the cylinder jacket and liner are not cooled to an abnormally low temperature as this condition will decrease the clearance between the hot compressor piston and the cylinder wall, thus inducing a sticky piston. A temperature differential of about 20°F. should be maintained between the incoming and outgoing water. If the incoming water is too cold it should be corrected by bringing the temperature to at least 70°F.

Loading

Under today's conditions, when restrictions delay delivery of replacement parts or make them unobtainable in some instances, cylinders may occasionally have to be used for pressures exceeding those for which they were designed. In such cases, extreme care should be exercised to keep the working pressure at or below that stipulated by the manufacturer of the cylinder. If the cylinder is to be used for pressures other than those for which it was intended, it is good policy to consult the manufacturer for his opinion as based on the changed operating conditions. Such practice will avoid damage to either the compressor or the mechanism that drives it.

Compression Ratios

Compression ratios should be kept as low as possible to prevent overheating compressor cylinders. Although overheating may not always damage the compressor cylinder, it may result in a temperature higher than the flash-point of the lubricating oil, in which case fires or explosions may occur, particularly in compressors operating on air.

Overheated conditions also lead to excessive carbon deposits in piston ring grooves and valves. A high ratio of compression in a compressor built for a low compression ratio, may also overload the piston rod and running gear.

Cleanliness

As with any fine piece of machinery, the compressor should not only be kept clean, but the operator should take steps to be certain the gas being compressed is as clean as practicable. Gases containing dust or other abrasives will soon wear the compressor piston rods, rings, and cylinder walls to such an extent that the compressor will require reboring and complete overhauling long before the normal time set for the work.

Corrosion

If the gas to be compressed contains any of the corrosive gases such as hydrogen sulphide, the manufacturer should be consulted for his opinion regarding whether the compressor can be operated satisfactorily for such service. Many times a few minor changes will render a standard compressor suitable for compressing highly corrosive types of gases.

Careful attention to the foregoing simple but important details will help greatly to assure peak operating capacity of compressor installations with a minimum of maintenance time and cost.

—— ☆ ☆ ☆ ——

P 094.8

Making a Brake Test Properly

by W. F. Schaphorst

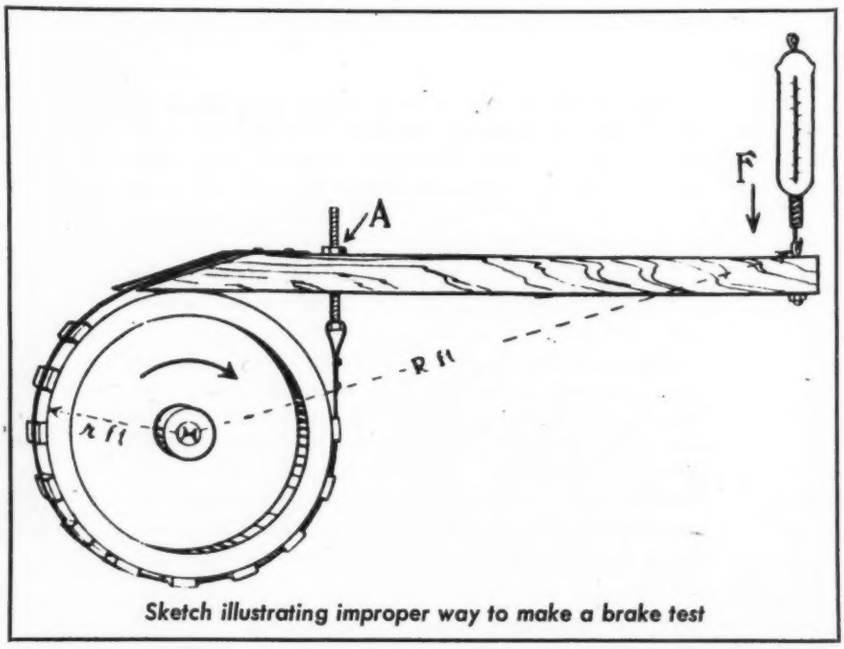
THIS "wrong" sketch for making brake tests is shown purposely because it emphasizes a common mistake. The dotted line from the center of the shaft to the contact point in the eye bolt — the connecting point with the scale — should be perfectly horizontal and should not slip upward as shown. Because this dotted line is not horizontal whereas the spring scale is vertical, the reading on the scale will not be a true measure of the pull on the eye bolt because the scale pull is not at right angles with the dotted line.

By making the position of the spring scale such that the dotted line will be horizontal — by lowering the scale — the effective pull as registered on the scale will be correct and the following rule can then be applied for determining the horsepower of the engine or motor that is being tested: "Multiply the horizontal distance R in feet by the pull on the scale in pounds, then by the r.p.m. of the shaft, and that by 0.00019". The result is the brake horsepower.

For example, if R is 3 ft., the pull on the scale is 100 lb., and the engine makes 1000 r.p.m.; substitute in the above rule and it will be found that it is a 57 hp. engine.

The principal thing to look out for, as mentioned, is: Be sure that line R is "square" with the pull exerted by the scale. That is, if the pull is vertical, line R must be horizontal.

—— ☆ ☆ ☆ ——



Sketch illustrating improper way to make a brake test

Correlation of Polished Rod Acceleration and Well Load

PETROLEUM ENGINEER Exclusive Feature

☆ Analysis of dynamometer cards in study of pumping wells

by Kenneth N. Mills

Works Manager, Texasteel Manufacturing Company

EARLY investigators of well pumping problems based all their theories on the assumptions that the motion imparted to the rod string by the surface machinery was simple harmonic, and that the entire mass of the rod string was instantaneously affected by this rate of acceleration. When more exact investigations were made into the nature of the polished rod motion, it was found to diverge widely from simple harmonic motion. The exact nature of the motion was found to depend on the geometry of the surface machinery and the speed regulation of the surface machinery.

The effect of the polished rod acceleration on the force required to reciprocate the rods would be very simple if the entire mass being accelerated was attached directly to the polished rod. This is not the case, however, as in an oil well the static weight of the well is distributed over a space of several thousand feet, and this distribution of mass introduces a time lag that must be considered if a useful solution to the problem is to be attained. This time lag will tend to reduce the magnitude of the dynamic forces acting on the system.

When attempting to evaluate the effect of polished rod acceleration on polished rod load, the facts that both the fluid and the rod string are elastic, and that the rate of polished rod acceleration imparted to the well by the surface machinery varies from zero to a maximum, must be considered. Due to the elastic nature of the rod string and the characteristics of the surface machinery, its entire mass is not accelerated at a uniform rate. The rod string can be considered to be made up of a series of small masses dm_1, dm_2, dm_3 . . . dm_i, which are equally distributed along its entire length, as shown in Fig. 1. The uppermost mass dm_1 will always be accelerated at exactly the same rate at which the polished rod is accelerated because it is directly connected to it. Due to the elastic nature of the rod string, a time interval T_1 will elapse before a force applied to the polished rod will be transmitted to the location of mass dm_1, which is located some distance l_1 from the surface. The equation for this time lag T_1 is:

$$T_1 = \frac{l_1}{V}$$

where:

T_1 = time lag, in sec.,
V = velocity of stress transmission in steel, in ft. per sec., and
l_1 = distance to mass dm_1, in ft.

As the instantaneous rate of acceleration at the surface is continually changing during each cycle and, therefore, changes with time, the mass dm_1 will be accelerated at some rate A_x when the mass dm_1 is accelerated at the rate A_1. Thus, each small section of the rod string is being accelerated at a different rate, and the entire mass of the rod string is not accelerated instantaneously at the same rate. The instantaneous value of the dynamic forces acting on the rod string at any instant is expressed by the following equation:

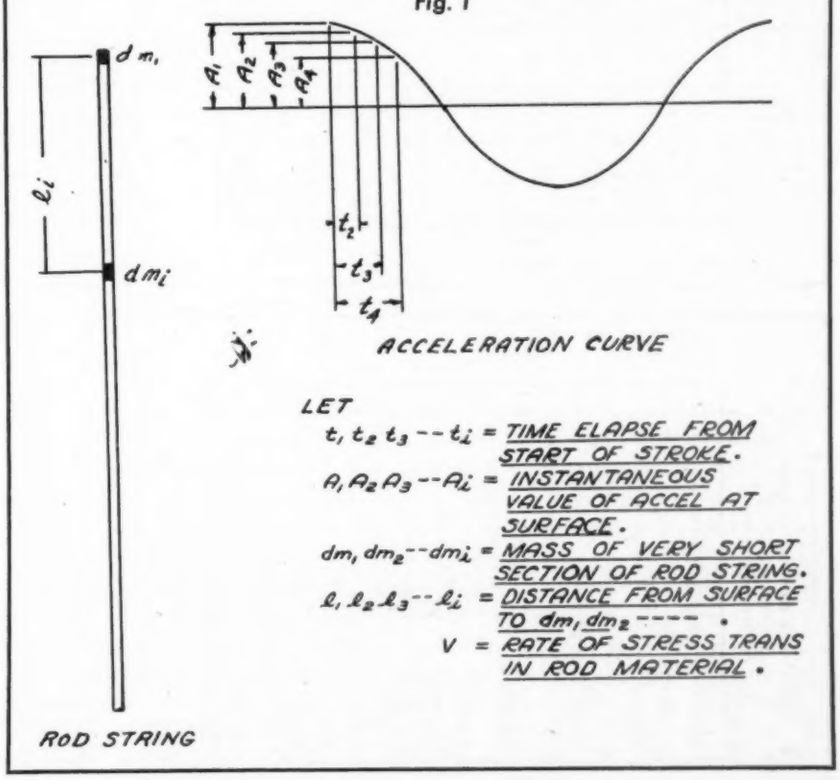
$$F = \sum_{l=L}^{l=o} A_x dm_1 + A_{x-1} dm_2 + A_{x-2} dm_3 + \ldots A_1 dm_i = MA_{AVG}.$$

where:

F = dynamic force,
M = total mass of rod string,
L = total length of rod string,
$A_1 = \ldots A_x$ = range of rates of acceleration over some time period $T = \frac{\text{Length of rod string}}{V}$, and
A_{AVG} = average rate of acceleration

From this equation it is apparent that, considering the rod string only, the magnitude of the difference be-

Fig. 1


dm,
li
dmi
A1
A2
A3
A4
t2
t3
t4
ACCELERATION CURVE
ROD STRING
LET
t, t2 t3 -- ti = TIME ELAPSE FROM START OF STROKE.
A, A2 A3 -- Ai = INSTANTANEOUS VALUE OF ACCEL AT SURFACE.
dm, dm2 -- dmi = MASS OF VERY SHORT SECTION OF ROD STRING.
l, l2 l3 -- li = DISTANCE FROM SURFACE TO dm, dm2 ---- .
V = RATE OF STRESS TRANS IN ROD MATERIAL.

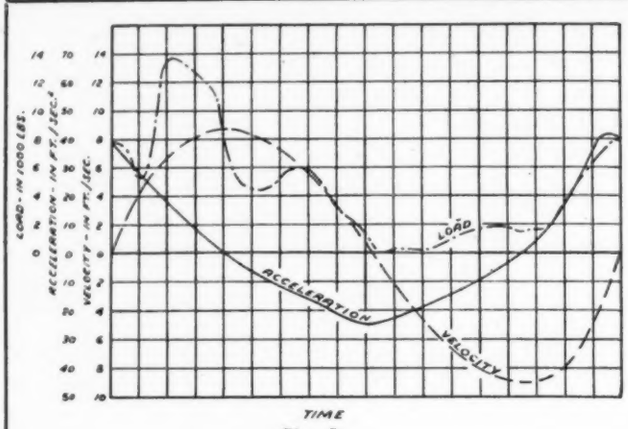


Fig. 3

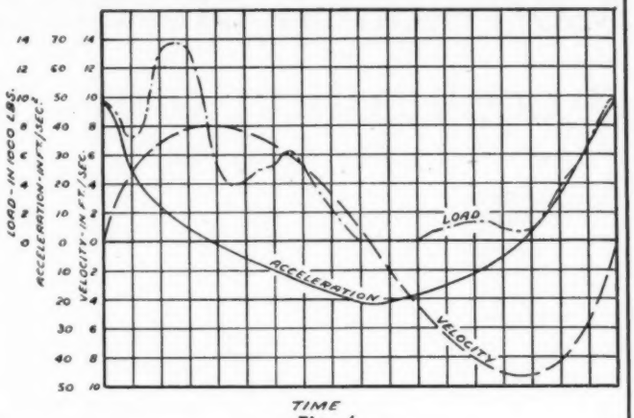


Fig. 4

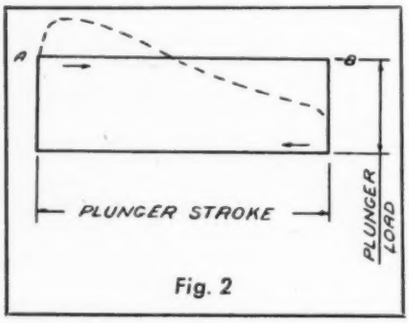


Fig. 2

tween the true acceleration factor and the apparent acceleration factor (acceleration factor based on the maximum rate of acceleration at the surface) will depend on the rate of change of the surface acceleration. If the rate of change is rapid, the difference between the true and apparent acceleration factors will be greater than it would be if the rate of change was less rapid.

The contribution of the fluid load to the dynamic forces is less susceptible to analysis than the part played by the rods. Pump dynagraph cards[1], which are load-space records taken between the rod string and the pump, indicate that the fluid load either is not accelerated or is accelerated at a uniform rate. A typical pump dynagraph card is shown in Fig. 2. The line A-B on this card indicates the magnitude of the fluid load acting on the pump. The fact that this line is substantially straight indicates either that the fluid load is not ac-

[1]"An Oil-Well Pump Dynagraph," by W. E. Gilbert, *A.P.I. Drilling and Production Practice, 1936.*

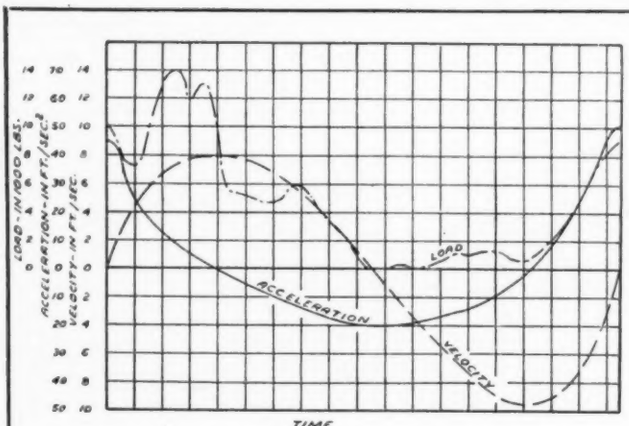


Fig. 5

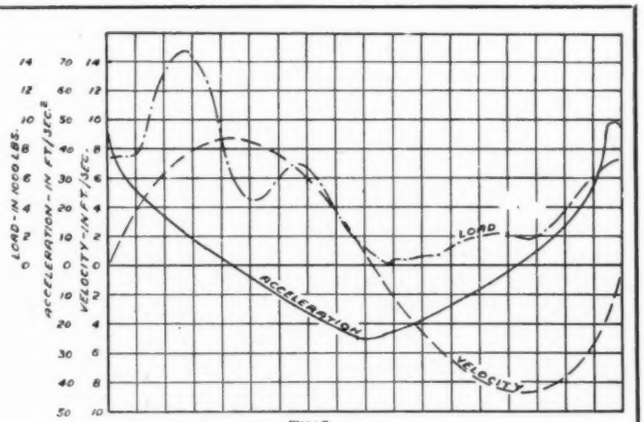


Fig. 6

Fig. 7

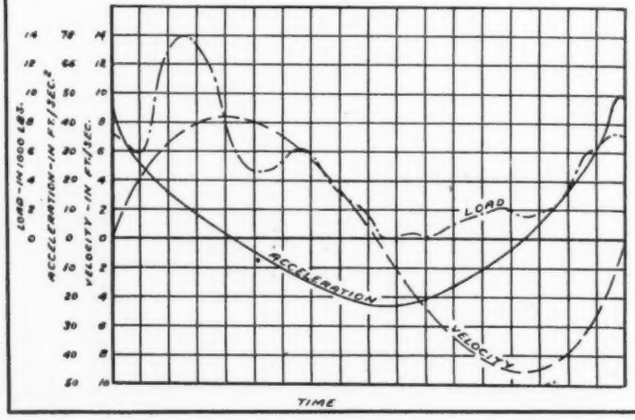
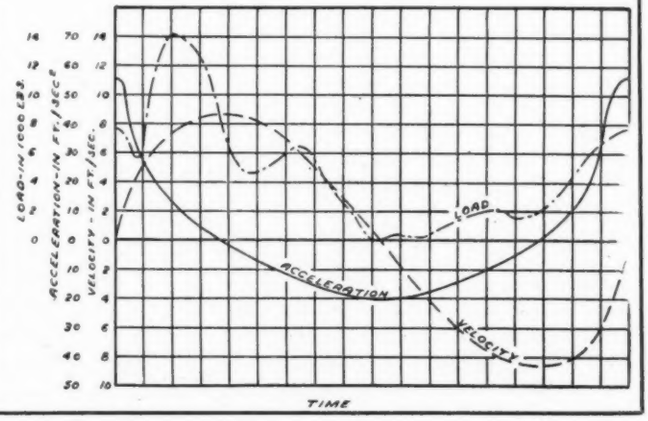


Fig. 8



Astonishing Savings When Using this Effective Pipe Wiper

Available in All Sizes

One of the largest oil companies, through its Engineering Department, reports that the saving in time alone, on one of their drilling outfits was enough to pay for their Patterson-Ballagh Pipe Wiper each trip. Before using the Wiper it required 2½ hours of circulation to get the mud back into condition. Based on their cost of $350 per day for well time figured $35 as the saving. This does not include the saving in weight material which is as much more, the insurance against dropping small objects into the well and increased speed due to cleaner floor.

MADE OF PBX ARTIFICIAL RUBBER

The Patterson-Ballagh Pipe Wiper is growing by leaps and bounds in popularity. Once used—always used. It is now made of PBX rubber which has proved exceptionally durable. Try it on one of your wells. Note how the crew "takes to it." There's nothing so effective as this wiper in saving time. Prompt deliveries.

See Composite Catalog

PATTERSON-BALLAGH CORPORATION

Los Angeles 1 Houston 10 New York City 6

PATTERSON-BALLAGH PIPE WIPERS

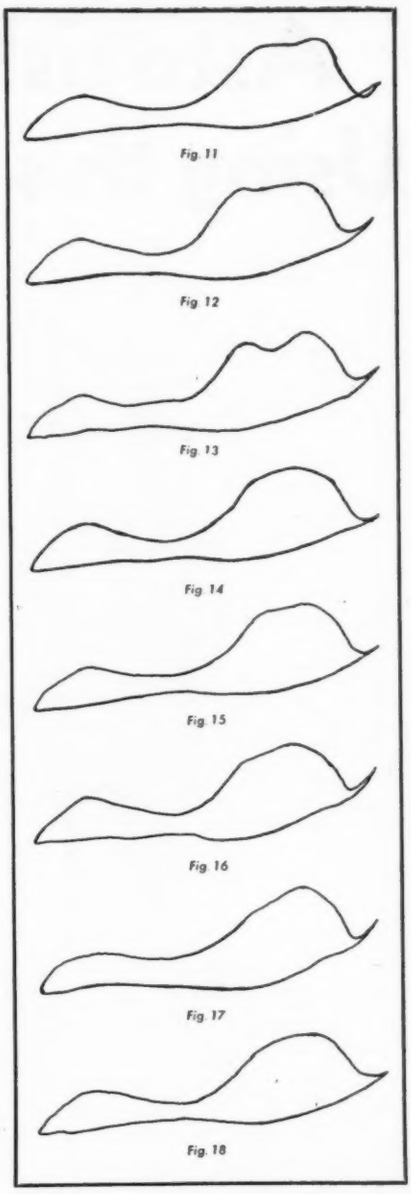
celerated or that it is being accelerated at a uniform rate. If the fluid load was accelerated at a variable rate comparable to the rate of acceleration imparted to the rod string by the surface machinery, the section A-B of this card would assume some shape similar to that shown by the dotted lines.

The characteristics of the fluid load acting on the pump are probably motivated by the conditions imposed on the two mediums by the impact set up by the valve action, the effects of tubing contraction and rod stretch, and the difference in the rates of stress transmission in the rod string and fluid column. When the traveling valve closes, impact energy is stored in both the rod string and the fluid column. The rod string stores this energy in the form of additional rod stretch, and the fluid column stores this energy in the form of fluid compression. These stored up impact energies are gradually released to the fluid column, and assist in its movement. As they are stored up during a period of relatively high acceleration, and are gradually released during a period of decreasing acceleration, they tend to promote a constant rate of fluid acceleration.

After the fluid load has been assumed by the rod string, and the rod string is attempting to set the fluid in motion, an increased load will be imposed on the rod string. As the rod string is elastic, it will stretch when this increased load is imposed on it, and this stretch will temporarily decrease the rate of motion imparted to the fluid by the rod string. As this decrease in the rate of motion occurs near the time of maximum acceleration, it tends to decrease the rate of acceleration imparted to the fluid by the rod string at that instant. As this energy will be gradually released to the fluid at a later instant when the rate of acceleration is decreasing, it will tend to promote a constant rate of fluid acceleration. During the early stage of this cycle of events, the tubing is contracting, and it is imparting some energy to the fluid. This event also occurs near the instant of maximum acceleration and tends to decrease the dynamic effect of the fluid load on the rod load.

The difference in the rates of stress transmission in the rod material and the fluid column is rather large, and this difference is the predominating factor tending to reduce the dynamic effect of the fluid load. The rate of stress transmission in steel is about 15,800 ft. per sec., and the rate of stress transmission in oil is about 4000 ft. per sec. The exact value of the rate of stress transmission in the oil will depend on the gas or water cut of the oil and, therefore, will vary widely. As the rate of stress transmission in the fluid is about one-fourth that in steel, a time interval about 4 times that required for a force to traverse the length of the rod string will be required for the same force to traverse the length of the fluid column. Thus, the average rate of acceleration that affects the entire mass of the rod string will affect only about one-fourth the mass of the fluid column. Friction and the abovementioned factors will reduce this average rate of acceleration to a value far below that acting on the rod string. The time lag introduced by the rod string and the fluid column will cause the resultant fluid motion to be out of phase with the polished rod and part of the fluid will be traveling upward when the polished rod is traveling downward.

Investigations[2, 3] of the factors influencing the shape of the surface dynamometer card have shown very conclusively that the shape of the card is determined by the ratio between the natural frequency of vibration of the rod string and the frequency of the pumping motion. The results of these investigations indicate that the vibratory stresses imposed on the rod string are the predominating dynamic stresses existing in the rod string. This is borne out by the shape of the lifting portion



[2] "Effects of Rod Vibration on Dynamometer Cards," by Kenneth N. Mills and S. E. Corry, *The Oil Weekly*, June 24, 1940.

[3] "Vibration Problems in Oil Wells," by J. C. Slonneger, *A.P.I. Drilling and Production Practice, 1937.*

Fig. 9

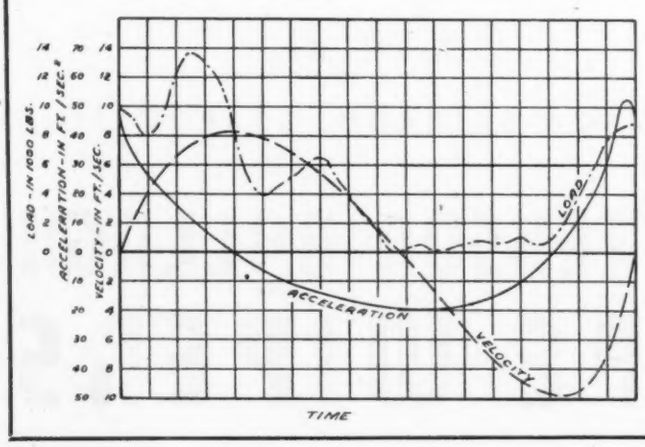
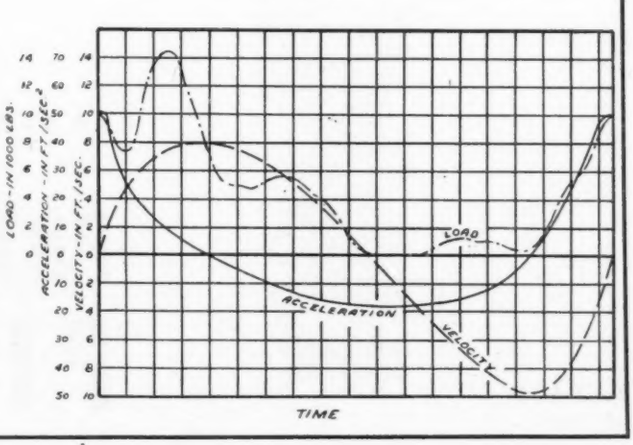
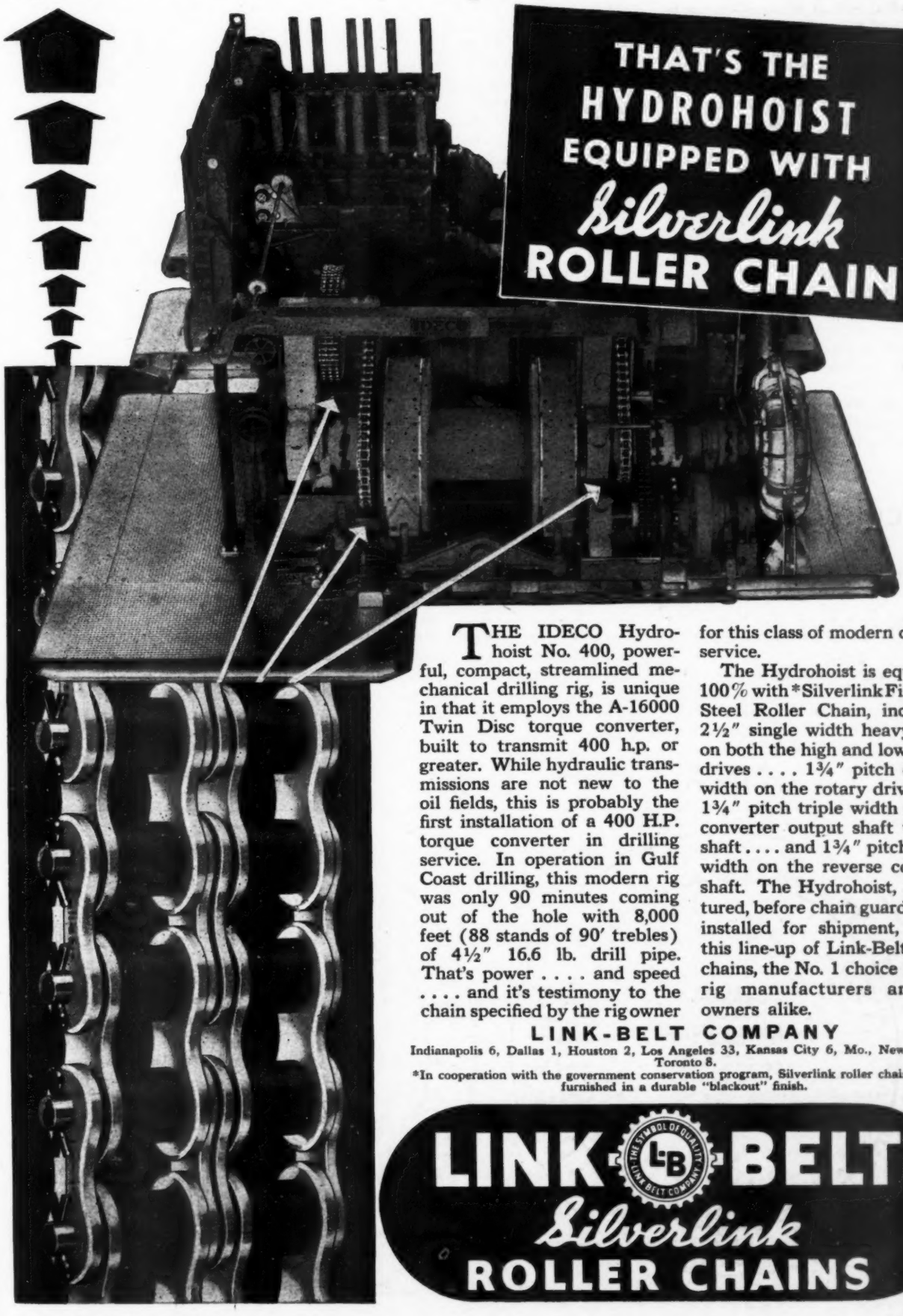


Fig. 10



8,000 Ft. of 4½" Pipe out in 90 Minutes



THE IDECO Hydrohoist No. 400, powerful, compact, streamlined mechanical drilling rig, is unique in that it employs the A-16000 Twin Disc torque converter, built to transmit 400 h.p. or greater. While hydraulic transmissions are not new to the oil fields, this is probably the first installation of a 400 H.P. torque converter in drilling service. In operation in Gulf Coast drilling, this modern rig was only 90 minutes coming out of the hole with 8,000 feet (88 stands of 90′ trebles) of 4½" 16.6 lb. drill pipe. That's power . . . . and speed . . . . and it's testimony to the chain specified by the rig owner for this class of modern drilling service.

The Hydrohoist is equipped 100% with *Silverlink Finished Steel Roller Chain, including 2½" single width heavy duty on both the high and low speed drives . . . . 1¾" pitch double width on the rotary drive . . . . 1¾" pitch triple width on the converter output shaft to line shaft . . . . and 1¾" pitch triple width on the reverse countershaft. The Hydrohoist, as pictured, before chain guards were installed for shipment, shows this line-up of Link-Belt roller chains, the No. 1 choice among rig manufacturers and rig owners alike.

LINK-BELT COMPANY

Indianapolis 6, Dallas 1, Houston 2, Los Angeles 33, Kansas City 6, Mo., New York 7, Toronto 8.

*In cooperation with the government conservation program, Silverlink roller chain is now furnished in a durable "blackout" finish.

8170

LINK-BELT
Silverlink
ROLLER CHAINS

of the load cycle on the dynamometer cards shown in this article.

The relationship between well load and surface rate of acceleration can be determined from the data recorded by the Westinghouse dynagraph. This dynamometer has a time cycle recorder built into it that records a series of waves on the dynamometer card. As the frequency of the recorder is constant, the length of each cycle represents a certain interval of time, and as the distance each cycle is spread over on the card represents a certain amount of polished rod travel, the average velocity of the polished rod over any cycle can be found from the data recorded on the card. These data can be used to plot a velocity curve, and the velocity curve can be mechanically differentiated to obtain an acceleration curve. As the data used to obtain these curves were recorded simultaneously with the well load, the velocity and acceleration curves thus obtained can be plotted in their correct phase relationship with the well load curve.

The results of applying the method of analysis to a group of dynamometer cards that were taken on one well are shown in Figs. 3, 4, 5, 6, 7, 8, 9, and 10. The dynamometer cards are shown in Figs. 11, 12, 13, 14, 15, 16, 17, and 18. The well from which these cards were obtained was 1980 ft. deep, and it was being pumped at the rate of 29 s.p.m. During the time these dynamometer cards were being taken, the amount of counterbalance was varied from proper counterbalance to no counterbalance. This change in counterbalance introduced varying degrees of cyclic speed variation into the system. This change in cyclic speed variation produced corresponding changes in the instantaneous rate of rod acceleration and the rate of change of acceleration during the cycle.

In each of these synchronized well load, polished rod acceleration curves it will be noted that the peak well load occurs within the first quarter of the lift stroke, and that the maximum rate of acceleration during the lift half of the stroke occurs at the start of this half of the stroke. Also, it will be noted that the well load gradually builds up to a maximum, and after reaching this maximum, it fluctuates widely. As this increase in well load occurs at a time when the rate of acceleration is low and is decreasing, it must be caused by the impulse set up by the closing of the traveling valve, and the assumption of the fluid load by the rod string. It has been shown that these fluctuations are the results of mechanical vibrations in the rod string, and these dynamometer cards indicate that these mechanical vibrations are one of the predominating factors contributing to the peak well load. The effect of polished rod acceleration on the well load seems to be most noticeable on the latter part of the downstroke. During this portion of the stroke, it is readily apparent that the increase in well load is not exactly in phase with the increase in the rate of acceleration, and that the effect of the acceleration is dependent on its rate of change during this period. ——— ☆ ☆ ☆

P 094.83

Calculator Computes I²R Loss in Wire Circuits

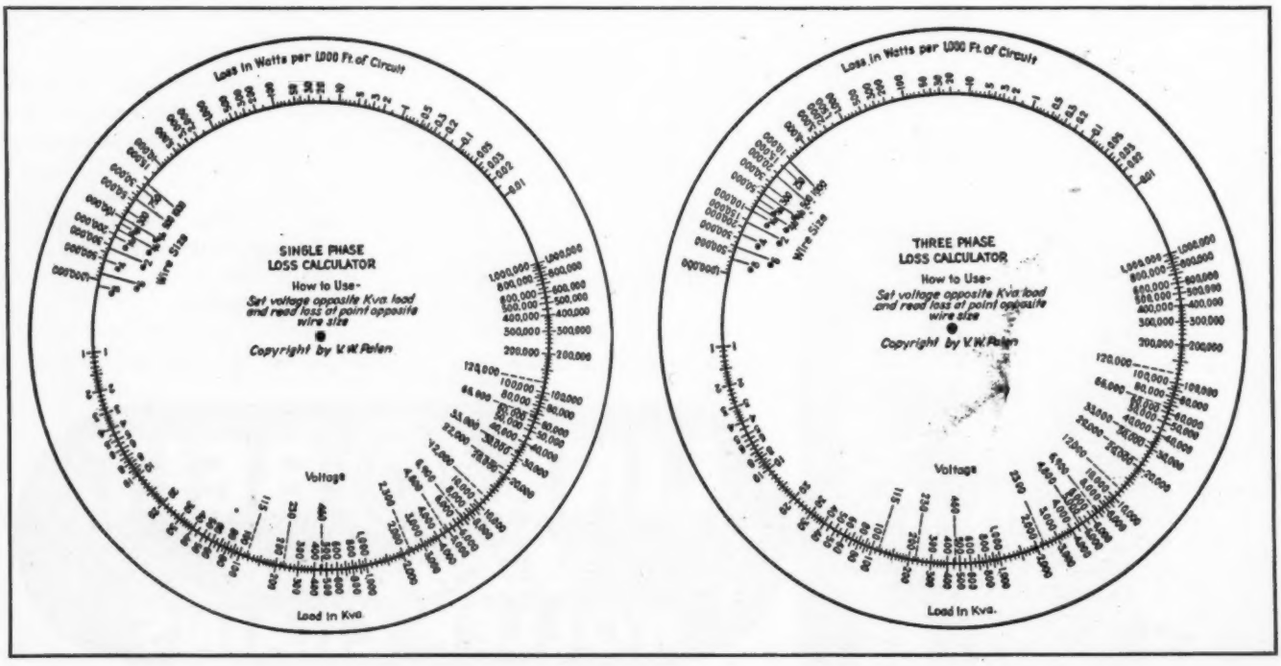
by V. W. Palen, Westinghouse Electric and Manufacturing Company

HERE is a device that determines I^2R loss in wire circuits with a flick of the finger.

Cut along the circles to make two disks and two rings. Using rubber cement, mount the disks on separate pieces of cardboard. On reverse sides of a third piece of cardboard mount the two rings. Now punch the center holes and insert a small brass bolt to hold the disks in place. Washers will help to prevent wear and tear on the paper. Tighten the bolt to provide the proper pressure on the disks—they should hold their settings, yet turn easily. A drop of solder applied to the nut will make the assembly permanent. The calculator solves the single phase equation: $\left[\frac{Kva}{Kv}\right]^2 \times 2R = W$

Where R is resistance of 1000 ft. of single conductor and W is watts per 1000 ft. of circuit. The three phase equation handled by the device is equivalent to the single phase relationship divided by two. Copper conductor is, of course, the basis of design—stranded on sizes No. 2 and larger.

——— ☆ ☆ ☆ ———


Loss in Watts per 1000 Ft. of Circuit
SINGLE PHASE
LOSS CALCULATOR
How to Use-
Set voltage opposite Kva load and read loss at point opposite wire size
Copyright by V.W.Palen
Wire Size
Voltage
Load in Kva.
Loss in Watts per 1000 Ft. of Circuit
THREE PHASE
LOSS CALCULATOR
How to Use-
Set voltage opposite Kva load and read loss at point opposite wire size
Copyright by V.W.Palen
Wire Size
Voltage
Load in Kva.

Recent Developments in Welded Refinery Equipment*

☆ Advancements in petroleum technology have necessitated newer and more complex equipment

by Russell J. Love

Chief Engineer, Southwest Welding and Manufacturing Company

PETROLEUM refining used to be almost as simple as boiling sea water to recover salt; but today the petroleum chemist is confronted with problems more complex than the separation of the magnesium, bromine, and iodine from the sea. Recent developments require the petro-chemist to use not only extraction methods other than absorption and distillation, but also to use chemical and catalytic reactions involving many reagents other than the natural hydrocarbons.

New equipment has had to be developed for this new petroleum technology. This paper will describe some of the recently developed equipment. There will also be presented some of the details of construction, with particular reference to the materials used, and the various welding processes for joining these materials.

The separate types of equipment in a modern refinery are too numerous to treat individually. Furthermore, much repetition would occur were we to consider refinery equipment in terms of refinery processes, such as alkylation, polymerization, thermal and catalytic cracking, and so on. The most interesting aspects of recently developed equipment may be summarized as due to the increasing demands for: (1) Higher operating temperatures; (2) higher operating pressures; (3) larger pressure vessels, and (4) better resistance to corrosion and abrasion.

These four topics will be discussed separately, although the conditions represented often occur all together.

High Temperatures

Operating temperatures of 750°F., and upward to 1100°F., are more and more frequently encountered. Thermal cracking, for quite a few years past, has employed temperatures from 850 to 1000°F. But some catalytic cracking processes now require operation at more than 1000 °F. At these temperatures metals are actually red hot. And for operation at red heat, the selection of materials and the design of equipment must take into account the following factors:

A. The high temperature strength of the material. (Resistance to creep.)
B. The possibility of temperature embrittlement.
C. The accelerated corrosion rates at high temperatures.

In meeting the three conditions (A, B, and C) present when high temperature is encountered, the materials used very greatly influence design of the equipment. Following are a few examples of design and fabrication considerations, as related to the material selected.

Straight carbon-molybdenum steel (ASTM A-204) may be selected for creep strength (factor A), but it may not satisfy the conditions of B or C. In other words, although the creep strength of carbon-moly is about twice that of carbon steel at 1000°F., operating conditions at this temperature may induce temperature embrittlement, or the carbon-moly steel may offer inadequate resistance to corrosion.

It has been found that the addition of chromium, even in relatively small amounts, to carbon-moly steel materially reduces the risk of temperature embrittlement, and may add to the creep resistance. As little as 1.25 percent chromium with 0.5 percent molybdenum may be used to satisfy factor A and factor B; but this small amount of chromium usually is not sufficient to improve the corrosion resistance very much.

The high temperature corrosion problem alone has three distinct elements: First, atmospheric corrosion, which at lower temperatures is almost no problem at all; second, the special type of heat corrosions encountered in those cases where equipment is direct fired, or in contact with hot furnace gases, and third, the corrosion due to the process fluids. A further discussion of the corrosion problem is included in the latter part of this paper.

When creep and embrittlement and corrosion are all expected, the economic solution is sometimes found in the use of plain carbon-moly steel for the pipe or vessel wall, to provide the necessary creep strength, plus the use of a liner of high alloy material to resist the corrosion or embrittlement that the process fluid would otherwise cause. The various forms that the liner may take, such as cladding, plating, or separately attached lining, will be discussed more in detail.

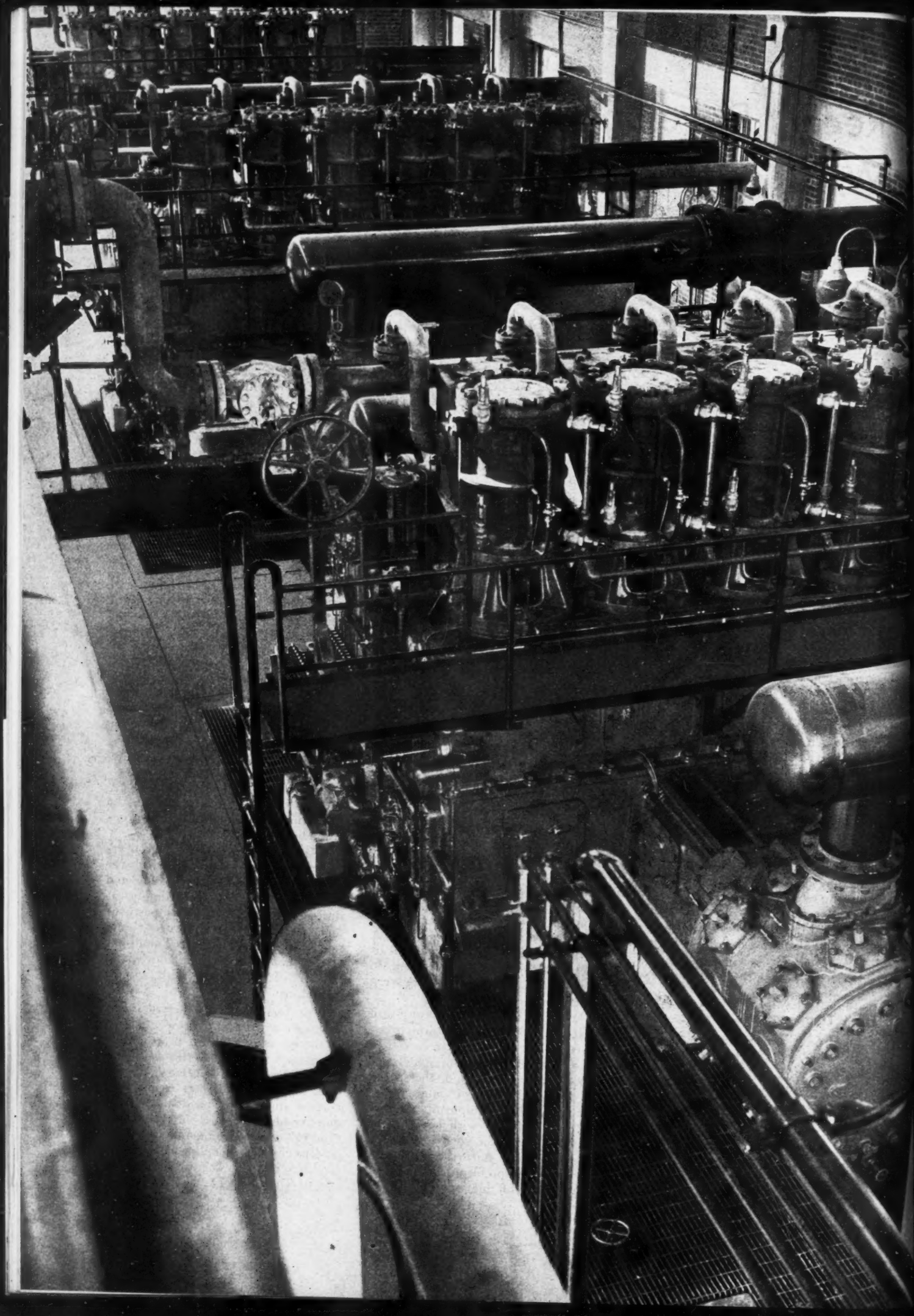
It is indeed fortunate that welding processes and techniques have been well developed for materials other than plain carbon steel. It is by virtue of the versatility of welding, that the alloy or composite materials often necessary for high operating temperatures can be fabricated in the size and shape necessary for almost everything from simple pipes to complicated heat exchangers. Moreover, welded attachment of alloy linings, whether by fusion plug welding or by resistance spot welding, is often the most economical method of providing such linings; and when clad material is used, though it may be costly, the cost is minimized if fabricated by proper welding methods.

Designing equipment for high operating temperature involves perhaps the most complex combinations of low and high alloy materials. Accordingly, at this point we will tentatively postpone topic No. 2, "High Pressures," and topic No. 3, "Large Vessels," and some of the methods of welding alloy materials and composite materials will be mentioned.

It has been found that electric fusion welding is entirely satisfactory for most of the low-alloy steels, if proper welding rods are selected, and the special preheating precautions necessary in some cases are observed. There is one low-chrome alloy, however, that has been quite troublesome. It is the type 501 or type 502 stainless commonly called 4-6 percent chrome. This alloy has a marked tendency to air harden in the tempera-

(Continued on Page 106)

*Presented before California Natural Gasoline Association, October 7, Los Angeles.



Offered in 3, 4, 5, 6 and 8-cylinder sizes ranging from 500 to 4,000 H. P.

Largest Butadiene Plant Uses Clark Steam "Angles"

10,440 B.H.P. IN PORT NECHES INSTALLATION

The world's largest Butadiene plant—Neches Butane Products Company, at Port Neches, Texas—will use CLARK steam-driven "Angle" Compressors to compress the series of gases which are handled in producing Butadiene.

The CLARK installation, part of which is here shown, will total six 8-cylinder 1740 B. H. P. units, or 10,440 H. P. These compressors will require 50 million pounds of steam daily for capacity operation, while the water cooling plant will handle 308,000,000 gallons of water per day, enough to supply a large metropolis.

This huge plant, operated by five major oil companies, will produce 100,000 tons of Butadiene annually, enough for 110,000 long tons of Buna S Rubber, and approximately one-seventh of the nation's requirement.

The CLARK Steam "Angle" offers the advantages of large capacity, small floor space, supreme fuel economy, low installation cost, low maintenance. It has established new records for operating economy. Our engineers are available for consultation without expense to you.

CLARK BROS. CO., INC. . . . OLEAN, NEW YORK
Export Office: 30 Rockefeller Plaza, New York. Domestic Sales Offices and Warehouses: Tulsa, Okla.; Houston, Tex.; Chicago, Ill. (122 S. Michigan Ave.); Boston, Mass. (131 Clarendon St.); Huntington Park, Calif. (5715 Bickett St.) Foreign Offices: 72 Tummill St., E. C. 1., London; Avda Roque Saenz Pena 952, Buenos Aires.

One of the Dresser Industries

CLARK

(Continued from Page 103)

ture range around 500°F., and any welding process employed is bound to create a temperature gradient extending into this air hardening range, unless something is done about it. What usually has to be done, is to maintain a preheat temperature above the air hardening range and conduct all welding operations at or above, say, 500°F.

Furthermore, the anneal necessary to stabilize the properties of this alloy must follow the welding without loss of the preheat temperature. In other words, to avoid the air hardening effect that may cause embrittlement or actual cracking of the material or the welds, a very elaborate setup is required, and much discomfort is involved for the welding operator. Because of these conditions, it is sometimes more practical to use the more expensive but easier to weld higher chrome alloys, such as 11-13 percent chrome, even though a lower chromium content would satisfy the operating temperature or corrosion problem.

The welding complications just described are often alleviated by the use of good old-fashioned acetylene welding, with its wider heated zone in the vicinity of the joint, but this process does not provide much of a protective envelope while the weld is being made. The atomic-hydrogen process is often superior, because it combines the ability to create a broad heating band, with a well-nigh perfect reducing atmosphere (the hydrogen envelope). Another welding process, the very recently developed Heliarc, or helium-envelope weld has not yet been applied to welding of the alloys encountered in modern refinery practice, so far as the writer knows.

In connection with the fabrication of apparatus by welding, the details of the shaping and preparing of the edges to be welded, are very important. The design of welded joints will vary according to whether:

(a) The joint is to be made in the shop or in the field,
(b) The size of the part being welded —which may determine whether both inside and outside welding can be done, or whether all welding must be from the outside only,
(c) The thickness of the main wall, and
(d) Whether the wall is clad or lined.

Space does not permit a complete discussion of the many types of welded joints for composite materials, but it should be mentioned that whenever there is a considerable difference between the composition of the main wall, (the "parent metal") and the composition of the cladding or lining, contamination is a serious problem. Contamination, sometimes called dilution, means either:

(1) detrimental dissolving of excess carbon from the carbon steel (or the dissolving of carbon steel itself) into the higher alloy steel, or,
(2) it may mean the contaminating effect of some of the alloying constituents migrating into the weld joining adjacent portions of the parent metal.

In case (2), the effect is usually bad because of the formation of an imperfect alloy in the weld itself, which may seriously weaken the joint. It is obvious that the strength of the vessel or pipe is dependent upon the joint between the parent metal, because the strength of lining or cladding is seldom if ever taken into account in the design. The pressure-vessel codes allow no credit for liners or the alloy portion of clad plates, in computing the strength of the vessel.

In case (1), the detrimental effect is primarily due to carbon pick-up spoiling the anti-corrosion properties of the alloy, or secondary effects such as checking.

Low Temperatures

While on the subject of temperature, and before proceeding to discuss high operating pressures, mention should be made of the present status of low operating temperatures in today's refineries. Although alkylation processes, cold acid treating, and solvent extraction all commonly use refrigeration, the low operating temperatures have not become materially worse from a design standpoint than those low temperatures encountered some ten years ago in solvent dewaxing. At that time, investigations were made of the special design problems incidental to low operating temperatures (about minus 100°F.), where the main difficulty was found to be that of low impact strength, and where the generally acknowledged answer was the use of nickel steel, containing from 2½ to 4 percent nickel. Such steel was found to be weldable, and is still commonly used for low temperature applications. Now, still speaking of cold temperatures, we can only

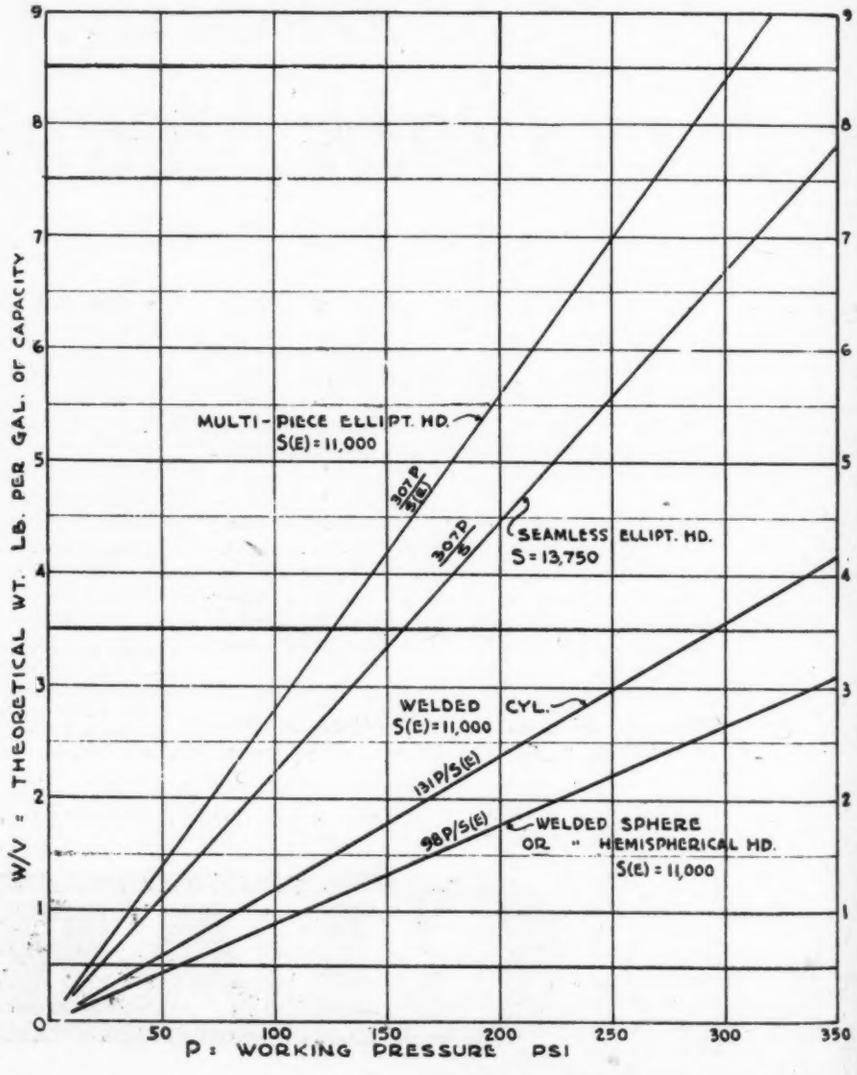


Fig. 1. Containers: Weight per unit volume for various pressures

WeldELLS

have everything ★

"You said it, brother—EVERYTHING!"

His job is *welding;* not fooling around getting ready to weld.

He can put more time on actual welding when he uses WeldELLS:*

—Because their tangents make them easier to line up.

—Because their precision quarter-marked ends simplify layout.

—Because the size and thickness are permanently marked on every fitting.

He can turn out a better job, too, when he uses WeldELLS—thanks to their dimensional accuracy and to the machine tool beveled ends that provide an ideal welding surface.

And the features that mean so much to the welder are also vitally important to the men who engineer the job and those who live with it.

★ No other fittings for pipe welding combine these features found in WeldELLS:

- **Seamless** — greater strength and uniformity.
- **Tangents** — keep weld away from zone of highest stress — simplify lining up.
- **Precision quarter-marked ends** — simplify layout and help insure accuracy.
- **Selective reinforcement** — provides uniform strength.
- **Permanent and complete identification marking** — saves time and eliminates errors in shop and field.
- **Wall thickness never less than specification minimum** — assures full strength and long life.
- **Machine tool beveled ends** — provides best welding surface and accurate bevel and land.
- **The most complete line of Welding Fittings and Forged Steel Flanges in the World** — insures complete service and undivided responsibility.

* WeldELLS and many other Taylor Forge products are produced in Byers Genuine Wrought Iron.

TAYLOR FORGE & PIPE WORKS, General Offices & Works: Chicago, P. O. Box 485

• The list of Taylor Forge's contributions to the war effort only begins with WeldELLS. One of many examples is Taylor Corrugated Marine Furnaces, essential to many merchant ships and transports.

NEW YORK OFFICE: 50 CHURCH ST. • PHILADELPHIA OFFICE: BROAD ST. STATION BUILDING

go down 460°F. below zero and no lower. Up toward the other end of the thermometer, however, getting back to H.O.T., even 1000°F. may not be the limit. According to one authority, thermal polymerization employs temperatures up to 1100°F., and "tomorrow" the industry may need to go still higher.

High and Super-Pressures

It is almost obsolete to refer to an absorber working at more than 400 lb. per sq. in as a high pressure absorber. Nowadays, one thinks of pressures from 750 to 1500 lb. per sq. in as high pressure, although the limits are very indefinite. Where high pressure ends and super-pressure begins is an open question. One authority considers pressures over 100 atmospheres, roughly 1500 lb. per sq. in., and up to 50,000 lb. per sq. in., to be super-pressures. Another states that the best definition is that we are dealing with super-pressure if the cylinder wall thickness exceeds 10 percent of the diameter. Suffice to say that high pressures, 500 to 1500 lb. per sq. in., are becoming quite common, and that full scale operation at 3000 lb. per sq. in. is not unheard of, and that at least one instrument company has a well developed line of laboratory and pilot plant equipment for up to 50,000 lb. per sq. in.

Even for the moderately high pressures around 1000 lb. per sq. in., the design of equipment must take into account many more factors than when dealing with only 100 lb. per sq. in. The designer of high pressure equipment must consider:

1. Suitable materials; carbon steel or high strength alloys.
2. Size and shape factors; see Fig. 1 and below.
3. Type of construction
   a. Rolled and welded; single plate wall, or multiple layers.
   b. Seamless: forged, drawn, or cast, or bored from solid.
   c. Combinations of a. and b., such as welded attachments on a seamless shell.

These factors will be considered in the order presented above. Selection of material for high pressure construction is almost always determined by making an economic balance between massive carbon steel and expensive alloy steel. This economic balance, however, involves more than simply material costs and fabrication costs; the availability and suitability of the material must be considered also. As in high temperature design, the action or reaction of the process fluid on the material is often of supreme importance. If high pressure is accompanied by high temperature, all

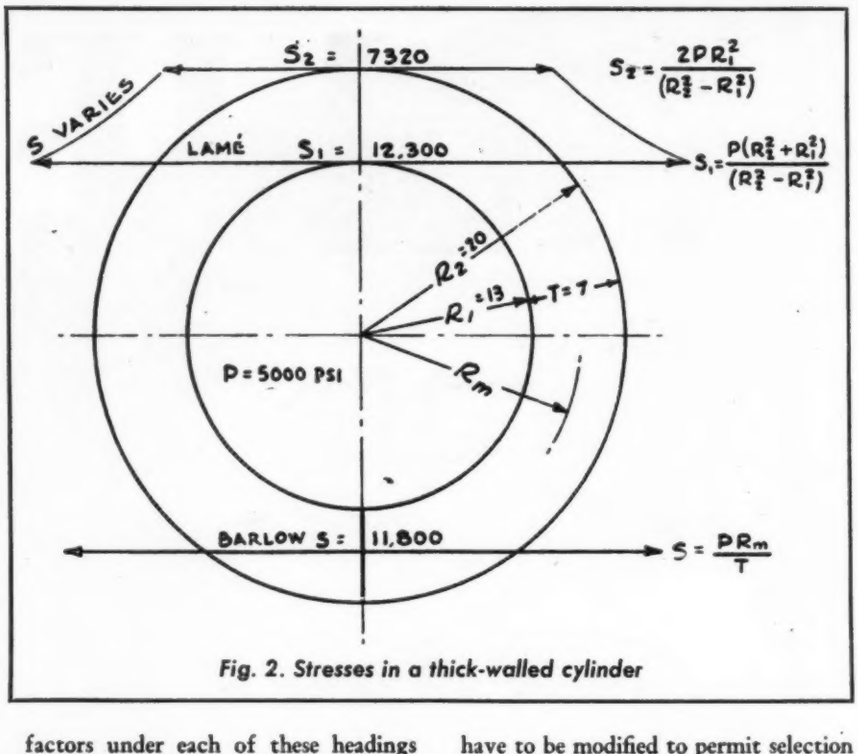


Fig. 2. Stresses in a thick-walled cylinder

factors under each of these headings must be considered fully. Fortunately, the materials outlined under the preceding discussion of high temperature, have higher-than-ordinary tensile strength, and hence are advantageous in meeting the requirements of high pressure. For example, carbon-moly steel, often selected for high temperatures because of its better creep strength, is available in three grades, A, B, and C, and has minimum (cold) tensile strengths respectively of 65,000 lb. per sq. in., 70,000 lb. per sq. in., and 75,000 lb. per sq. in. Another example is to make the main wall of the vessel of the strongest suitable inexpensive material, and employ a liner to meet the heat or chemical-corrosion problem. For instance, a fusion welding piping assembly for pressure at high temperature (pipe fabricated by rolling and welding clad plates), has carbon-moly base metal with 18-8 stainless cladding, the carbon-moly to provide strength at high temperatures, and the stainless to provide resistance to corrosion of the flowing catalyst.

When high pressure alone is being considered, uncomplicated by high temperature or severe corrosion, the lowest cost high strength steels are carbon-silicon (ASTM A94, A201, and A212) or carbon-manganese (A-225). Until side-tracked by the advent of the present war, the low alloy steels known as Corten and Mayari-R, also provided a low cost high strength material, both easily workable and easily weldable.

In high pressure vessels, shape and size are not mere factors of convenience. The process requirements for size may have to be modified to permit selection of an economic design. The cost per cubic foot of capacity becomes a matter of much money when pressures of 1500 lb. per sq. in and upward are encountered. Small diameters minimize the cost, but some reactions, particularly catalysis, may require as large an area or volume as possible, hence the need for balance between the factors of size, shape, material, construction, and operation.

The type of construction to be employed in a vessel for high pressure will determine to some extent what materials may be employed. For instance, in seamless forged, or bored-from-the-solid, or cast vessels, high strength may be provided by high carbon content alone. Doing so, however, may preclude the possibility of making any attachment by welding. As has already been pointed out under the discussion of high temperature, carbon-moly, or the stainless steels, whether used as the main vessel walls or as liners, can readily be welded.

Welding has also made possible some very interesting combination designs for high pressures, such as long-stroke pumps made by welding two or more forged steel parts together; the welding of the outer barrels for Hydropress pumps, and the familiar examples of welding forged or cast steel nozzle flanges onto seamless necks.

Welding has made possible the recent development of multiple layer pressure vessels, an example being a vessel in hydrogenation service at high temperature; it is 36 in. inside diameter, built of 20 layers, for a working pressure of

Postwar thoughts are

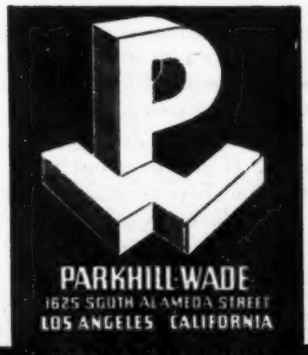
interesting—Important—NECESSARY

however

War Plants still demand our every effort

Important wartime needs have been and are being met, not only along engineering lines and in field construction of necessary wartime plants, but also in the fabrication of vital equipment in our own shops.

Distillate Recovery Plants
Gas Dehydration Plants
Compressor Stations
Natural Gasoline Plants
Stabilization Plants



Our ability to handle all phases of projects tends to speed completion and assures efficient, economical installations.

AFFILIATED WITH

THE STEARNS-ROGER MANUFACTURING CO.

1720 CALIFORNIA STREET • DENVER, COLO.

3000 lb. per sq. in. Whenever possible all connections leading into multiple-layer vessels are made through the head, inasmuch as nozzle attachment to the laminated shell is something of a problem.

As the high pressures and super-pressures being discussed very often involve thickness-to-diameter ratios of more than 10 percent, and when this relation exists, specialized formulas should be used, Fig. 2 has been prepared to show the difference between the usual Barlow formula for computing ordinary pressure vessels, and the Lamé formulas for thick-walled vessels.

Supersize Equipment

Among the most outstanding, literally outstanding, features of the newer refineries, particularly those producing synthetic rubber ingredients and toluene, is the supersize of some of the vessels, and the structures for them. This is not only because of large throughputs or large outputs (some of the plants probably wish their outputs were larger), but because of the process requirements; viz: Superfractionation involves more and more trays, which means higher and higher towers. Semi-batch processes require very large volumes to maintain some semblance of continuous flow with reasonable off-stream, on-stream cycles. Catalytic reactions often require catalyst beds with large areas or volumes.

The recently developed equipment and apparatus exemplifying supersize can best be described by citing a few case histories as follows:

Case 1. A de*iso*pentanizer tower now being built is 96 in. diameter by 175 ft. high overall, contains 70 bubble trays, and weighs 150,000 lb. without the trays. It is designed to be self-supporting, having an extended base heavily reinforced. Although the topmost part of the shell is only ⅜ in. thick, such factors as resistance to earthquake, hydrostatic loads and wind loads, require that the shell be thicker and thicker toward the base, and we find the thickness of the lowest course to be 1-3/16 in. In fact, the thickness-to-diameter ratio of the lower 68 ft. of the shell height is such that that portion must be stress-relieved to comply with the API-ASME Code. This is truly a superfractionator.

Case 2. Very tall bubble towers, even though nominally self-supporting by virtue of properly designed bases, may suffer troublesome vibration if they are very slender. Typical of the modern treatment of this problem, is the case of a fractionating column only 4 ft. dia. but more than 90 ft. high, which required bracing. Instead of a multiplicity of guy wires attached at various elevations, which would have formed a network overhead, it was decided to use harmonic sway bracing, consisting of three trusses equally spaced around the circumferences of the tower. Each truss consisted of a steel cable attached at the top and bottom of the tower by welded clips, and each cable was spread at the center by a 3 ft. strut. Singing, or vibration of the truss wires themselves is avoided by using vibration dampeners between the turnbuckles and the attachment at the bottom of the column.

Case 3. A typical reactor for a fluid catalyst cracking unit is 27 ft. dia. by 87 ft. high, having 50 ft. of this height the full 27 ft. diameter. The top head is a 90 deg. cone, the bottom head is similar except that it has a 10 ft. diameter by 13 ft. deep sump appended. The main support ring is at the bottom of the 27 ft. shell, where the vessel rests on a special elevated structural support. The main shell is 1½ in. thick, the cone heads 2 in. thick, and the entire vessel is made of Pluramelt (a clad plate, in this case with 20 percent type 347 stainless on the inside, the remaining 80 percent of the thickness being carbon-silicon high tensile plate.) Although the operating pressure is low, the operating temperature is about 1000°F. The required stress relief was the subject of debate: Whether to stress-relieve in the field by building a fire inside, or whether to let the 1000°F. operating temperature do the trick.

Case 4. A typical catalyst regenerator operates at 1100°F. (red hot), is 42 ft. in dia. by 35 feet straight shell, and has a 90 deg. cone bottom. The top is a practical combination of cone and dome, having about ⅔ composed of 90 deg. cone, and the upper ⅓ bridged over with a portion of a sphere. Just a chamber, having no internal parts, but being constructed of 1 in. plate for the shell and 1¼ in. plate for the cones, it weighs more than 200 tons empty. Because the catalyst flow from this regenerator is by gravity, this whole vessel is mounted at the topmost part of a structure built like a 20 story building. The operating temperature (1100°F.) will do the stress-relieving.

Case 5. Typical catalyst hoppers are 30 or 32 ft. dia. by about 80 ft. high overall, and have conical bottoms and full hemispherical top heads. Design is for 5 lb. per sq. in. working pressure at 650°F. As in the case of very tall fractionating towers, the shell thickness varies from top to bottom. These hoppers are about ½ in. thick at the top and each course of shell plate, proceeding downward, is usually 1/16 to 1/8 in. thicker, making the bottom course about 1 in. One hopper weighs, empty, over 250,000 lb.

Case 6. Although standard API storage tanks continue to be generally used, with cone roofs or floating roofs, for storage of low vapor pressure fluids, there has been an interesting development of containers for high vapor pressure fluids. Spheres and spheroids, are adaptable to pressures from 10 to 100 lb. per sq. in., and volumes up to tens of thousands of barrels. Large diameter vertical pressure containers and supersize horizontal cylindrical tanks have been used and are now being constructed for pressure storage of liquids. An example of a recently developed special design of horizontal pressure tank of large capacity is located in Southern California. It is 38 ft. in dia. by 114 ft. long, for a working pressure of 60 lb. per sq. in. The novel feature is the method of support. Instead of two piers or cradles, which would require two ring girders to maintain the tank round at the points of support, and would involve sliding bearings or rockers at one end to allow for expansion, a transverse central support is used. The ring girder at this point is inside the tank shell, and so the whole thing looks like a blimp almost floating in mid-air. The advantages, of course, are freedom to expand and contract, or to curve under the differential heating of the sun's rays, and, it is asserted, ease of field erection resulting in low cost per gallon of contents. Reference to Fig. 1 will show that, in comparison to spherical containers, the cylindrical type is not at such a disadvantage as many believe. Just because for a given pressure and diameter a sphere needs to be only half as thick as a cylinder, does not mean that the weight or cost of a sphere will be half that of a cylindrical tank for a given capacity.

The transportation and construction problems in building supersize vessels are many. Superfractionators often require shipment in two or more sections, to be joined by welding in the field, usually before erection. The gargantuan catalyst equipment obviously cannot be shipped fully assembled. Erection becomes a matter of assembling, plate by plate, the individual pieces after prefabrication and transporting to the site. Even so, rather heavy lifts are involved in building those vessels with plate thickness over 1 in.; e.g. an 1½ in. plate 8 ft. wide by 30 ft. long weighs 15,000 lb., and such plates must be lifted to fantastic heights to assemble a catalytic reactor, say, on the 14th floor of the building. Field welding of these vessels, as is evident from the construction details given in the case histories, may involve all the problems connected with welding of composite materials as discussed under the topic of high temperature. Doing such welding in the field, means that every precaution

WOULD YOU LIKE A PRIZE "CAT"?

One of Phillips prize "cats" can do more than add nine lives to your refinery. The right "cat"—and Phillips has many catalytic processes from which to choose—will keep your plant modern and up to date.

Phillips has developed and commercialized a large number of catalysts and catalytic processes. Let our engineers show you how Perco "Blue Ribbon Cats" can help you to produce more and better high octane gasoline so urgently needed in today's war period and to better meet the competition in the manufacture of motor fuel in post-war tomorrow.

Some of the Phillips Catalytic Processes available to you

CYCLOVERSION
DESULFURIZATION
HF ALKYLATION
ISOVERSION
CRACKING
REFORMING
HYDROGENATION
DEHYDROGENATION
POLYMERIZATION
DEPOLYMERIZATION
ISOMERIZATION
COPPER SWEETENING
GAS MANUFACTURE
RETREATING

PROCESSES ★ ENGINEERING
PERCO
RESEARCH ★ CONSTRUCTION

Division of

PHILLIPS PETROLEUM COMPANY, *Bartlesville, Oklahoma*

must be taken to insure not only the safety both of the men and materials during construction, but also safety of operation of the finished vessel.

Corrosion and Abrasion

All the "old" corrosion problems are still with us, and a host of new ones are at hand. As has already been mentioned, any or all corrosion is aggravated by the higher temperatures of operation. Many of the old corrosion probems were adequately solved by simply providing extra metal for corrosion allowance. Most of the new corrosion "gremlins" are not stopped that easily. The prevention of chemical attack, of heat or stress corrosion, of embrittlement, and of hydrogen penetration, may require the most expensive materials and the best fabrication knowledge available. Do not expect this brief study of equipment to answer all the new corrosion questions. Just a few of the things that are being done will be reviewed; some of these things are only trial attempts to find out the answers.

The use of substances heretofore foreign to refinery operations requires the careful adaptation of materials equally foreign to the usual refinery experience. Here are a few examples.

Hydrochloric acid may occur in such form and such concentrations that only a very high alloy like Hastelloy will endure. In one such case, a liner of Hastelloy is installed in the lower section and bottom cone of a tower, and also within the necks of certain nozzles. Attachment is by plug welding, except that small diameter nozzles may be of solid Hastelloy. Because this alloy costs several times as much as 18-8 stainless steel, its use is generally limited to zones of expected corrosion where nothing else will do. In welding Hastelloy the welds tend to be porous; remelting of the weld in a carefully controlled atmosphere boils out the porosity and gives a smooth bead. The atomic-hydrogen arc is especially well suited to this "sealing" operation, but the acetylene flame also can be used successfully.

Anhydrous hydrofluoric acid is another of the newcomers. When most of us were first introduced to hydrofluoric, we learned the salient property was that it couldn't be kept in glass bottles, and this property has earned for HF an undeservedly bad reputation for supercorrosion. Just like concentrated H_2SO_4, and anhydrous HCl, according to C. M. Fehr, anhydrous HF can be tolerated by any good steel. By contrast, at concentrations over 65 percent it attacks lead rapidly. Welded or cast steel equipment, therefore may be used, but be sure that the acid is known to be anhydrous, or nearly so.

Ammonia is not only a refrigerant but also is a reagent or catalyst, as in modern toluene plants. Some of us may need the reminder not to use brass or copper in ammonia's presence, not even to braze a cracked compressor head, if the ammonia is to be held.

Hydrogen sulphide, no newcomer to the group of corrosion gremlins, nevertheless brings new headaches when it appears in some of the new processes. In one case where H_2S was present at a temperature of 900°F., the piping and accessories had to be stainless steel, 18-8 with 3 percent moly. In another case, this insidious compound H_2S had to be got rid of because it acted as a poison spoiling the action of phosphoric acid as the catalyst in making polymer gasoline. In absorbing or otherwise separating H_2S from a gas stream, a weak acid may be formed and lead* lining may be needed to avoid this corrosion.

The non-ferrous materials, notably copper and Everdur, Monel, Inconel, and nickel are becoming increasingly useful in meeting new conditions of corrosion, or in some cases conditions requiring non-contamination of the products by iron. Fortunately, the chemical process and food industries in solving similar problems caused the development of dependable methods of working these non-ferrous materials into exchangers, pressure vessels, etc. This "know how" will be very useful to the new petro-chemical industry.

Some reactions with the metal walls of equipment cause chemical deterioration of almost all materials of construction. Caustic embrittlement is one; the new processes are bringing more, like hydrogen attack.

Many of the newer cracking and reforming operations involve dehydrogenation. In these, as well as in the direct hydrogenation process, the presence of free hydrogen may cause the phenomenon known as hydrogen penetration. This causes progressive deterioration of the steel and to date, (I am told) no fully satisfactory remedy has been found. Vessels have been made with walls twice as thick as would otherwise be required but the hydrogen seeps through.

Now, a word about abrasion. Without referring too specifically to the mechanism of the several new catalytic processes, it may be said that at least two of them use finely divided solids as catalysts, and these fine solids are caused to flow in suspension in fluids. During this flow, and in the subsequent separation (in one process) the solid particles act abrasively. Equipment handling this mixed flow condition may be either of abrasive-resistant material like the workable low manganese alloy steels, or, the anti-corrosion claddings or liners by virtue of their generally better physical properties — hardness and tensile strength—may offer long enough life to get by. And if temperature permits, we should not overlook the fact that rubber linings, good for both abrasion and/or corrosion, are available on high priority.

Conclusion

The development of the new applied-science of petro-chemistry is just beginning. As new processes, new reactions, new catalysts are discovered and new products are developed from petroleum, there will be more new equipment — perhaps unlike any we have yet seen. That is the only conclusion with which this article can end. —— ☆ ☆ ☆ ——

*If temperature permits.

Signs to Meet the Future

"Undeveloped and undiscovered supplies will fill the nation's oil needs for many years to come . . . the alarmists are extrapolating an immediate situation under emergency conditions wherein consumption has been suddenly expanded beyond the normal rate, and these emergency conditions have restricted the facilities for new discoveries."

—Dr. Joseph T. Singewald, chairman of the John Hopkins University geology department.

"The only thing the petroleum industry needs to provide this country an adequate supply of oil so long as oil is available anywhere in the world is the assurance that it will be free of government restrictions and interference, and be assured of a fair margin of profit for its efforts."

—E. H. Moore, senator from Oklahoma.

"I have been unable to discover any method of stimulating oil exploration and production in this country except through an increase in the price of crude oil."

—Petroleum Administrator Ickes to Economic Stabilizer Director Vinson.

Packers-

to meet a specific need ! !

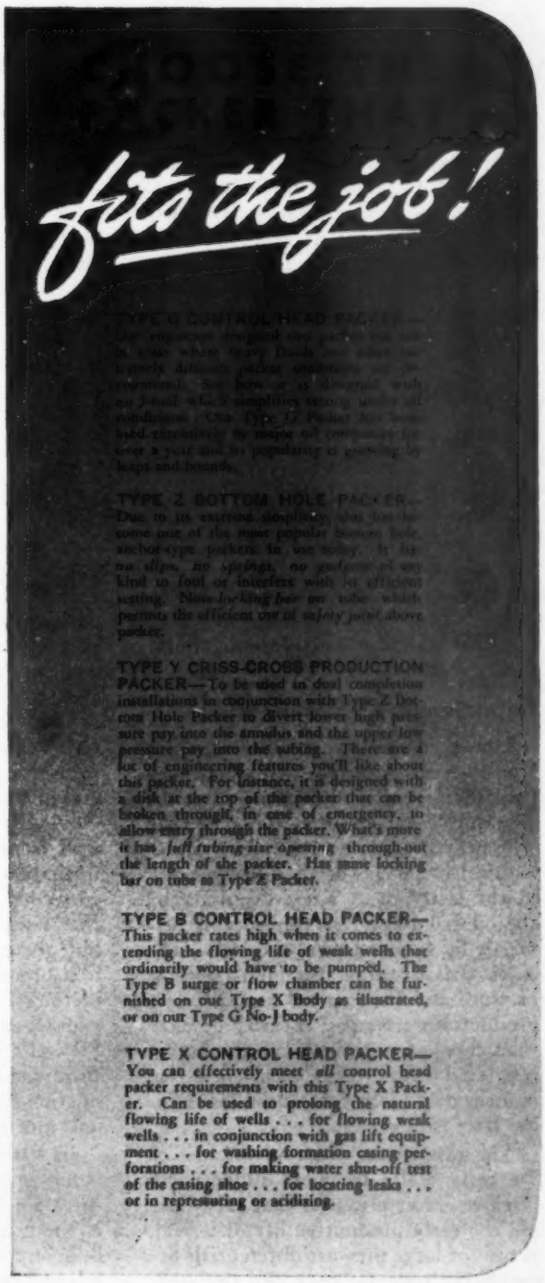
Why 5 packers?

Every producer should read this answer . . .

IF you have ever tried to run a packer in heavy fluids or under other extremely difficult conditions, you know that *no single packer* can be used efficiently and economically on every packer job today. The conditions encountered in wells in one field may differ entirely from the conditions faced in another—and your type of packer may have to differ with them.

For the *right* performance, it takes a packer that's *built to fit the job!* That's why the American Iron & Machine Works Co. now offers *5 great packers* . . . each designed and engineered to meet a specific need.

But remember this—even though these packers differ in design, each packer has our famous *horizontal expanding, non-sticking packing elements.* And each packer has been designed and built by the same skilled engineers and craftsmen who have won for American Iron and Machine Works Co. packers such a great reputation for economical and efficient operation. For the *right* packer to *fit your job,* see your nearest American Iron & Machine Works Co. salesman or your supply store.


fits the job!
TYPE Z BOTTOM HOLE PACKER—
TYPE Y CRISS-CROSS PRODUCTION PACKER—To be used in dual completion installations in conjunction with Type Z Bottom Hole Packer to divert lower high pressure pay into the annulus and the upper low pressure pay into the tubing. There are a lot of engineering features you'll like about this packer. For instance, it is designed with a disk at the top of the packer that can be broken through, in case of emergency, to allow entry through the packer. What's more it has *full tubing size opening* through-out the length of the packer. Has same locking bar on tube as Type Z Packer.
TYPE B CONTROL HEAD PACKER—This packer rates high when it comes to extending the flowing life of weak wells that ordinarily would have to be pumped. The Type B surge or flow chamber can be furnished on our Type X Body as illustrated, or on our Type G No-J body.
TYPE X CONTROL HEAD PACKER—You can effectively meet *all* control head packer requirements with this Type X Packer. Can be used to prolong the natural flowing life of wells . . . for flowing weak wells . . . in conjunction with gas lift equipment . . . for washing formation casing perforations . . . for making water shut-off test of the casing shoe . . . for locating leaks . . . or in repressuring or acidizing.

AMERICAN
IRON AND MACHINE WORKS CO.
OKLAHOMA CITY, OKLAHOMA
Houston and Monahans, Texas; Harvey and New Iberia, Louisiana
Great Bend, Kansas. *Export Office:* 420 Lexington Avenue, New York City.
California Representative: Hopper Machine Works, Inc., Bakersfield, Cal.

Time As a Factor in Economics Of Oil Field Exploitation

PETROLEUM ENGINEER Exclusive Feature

☆ Determining when to drill, the most advantageous rate of production, and productive life period of a property, are essential to ultimate profit

by Lester C. Uren

Professor of Petroleum Engineering, University of California

PREVIOUS articles of this series, reviewing the problems of oil field development, have been concerned with the oil well spacing problem. A closely related problem in which many of the considerations that enter into well spacing will again find application, is that of the timeliness of drilling and the procedure to be followed in determining the period within which maximum profit will be obtained in the exploitation of an oil producing property. Early in the development of every oil field, owners of tracts within the prospective producing area are confronted with the necessity of deciding when the various wells shall be drilled and, within the limitations of proration restrictions, the most advantageous rate of production and the economic productive life period of the property. As in the case of well spacing, we shall find it impossible to evaluate and formulate all the factors involved, but a practical solution of this problem is essential and much of the potential profit may be sacrificed if, as a result of insufficient consideration, decisions are reached that are not in accord with the physical and economic conditions presented.

Importance of Timeliness

Under competitive conditions, there are powerful incentives that compel the operator to drill and produce his wells as rapidly as possible. This is true whether the field is producing under water drive or gas drive, but especially in the latter case. When expulsion of the oil from the reservoir rock is primarily by gas expansion, the early wells enjoy the advantages of high reservoir pressure and their initial and ultimate productions are substantially greater than those of later drilled wells. In unrestricted fields, delay of even a few months may mean substantial losses for the later drilled wells.

The reasons for these advantages of the early wells are well understood. High reservoir pressures that exist during the early productive life of a field, permit of large pressure differentials between the reservoir rock and the well; fluids move more rapidly through the reservoir rock and wells create drainage influence over wide areas. Oil, saturated with dissolved gas under high pressure, has lower viscosity and flows with less resistance through the pore spaces of the reservoir rock than at lower pressures when much of the gas has escaped from solution and the oil is of higher viscosity.

Early wells develop pressure influence over wide areas and, in permeable formations, the pressure of the reservoir fluids is rapidly depleted. Based on the D'Arcy formula expressing the relationships existing between the factors influencing flow of liquids through porous media, Muskat offers the following equation for computing radial flow to a well through a reservoir stratum:

$$Q = \frac{2\pi K T P}{Z \log \frac{L}{r}}$$

In this expression, Q = the rate of flow; T = the thickness of the reservoir rock; L = the radius of drainage; r = the radius of the well; Z = the viscosity of the fluid; P = the differential pressure between the formation and the well, and K = the coefficient of permeability of the reservoir rock. Inspection of this formula shows that the productivity of a well is directly proportional to the pressure differential and inversely proportional to the viscosity of the fluid. Obviously, the rate of production of a well is materially increased when the formation pressure is high and the viscosity of the fluid is low; conditions that exist during early life of a field but are progressively altered as depletion proceeds. Clearly, where expulsion of the oil is by expanding gas, it is advantageous for the operator to complete his wells as early as possible and give them the advantage of maximum production time under conditions that exist only during this early period.

In water drive fields, the time factor is not so important, for reservoir pressures are substantially maintained and if the pressure does not fall below the bubble point of the oil, no gas will be released from solution and the viscosity of the oil does not vary. Yet, even under these conditions, early completion of wells is important. All wells produce under an equality of conditions from what is essentially a common reservoir. A well does not share with others in the field in this production until it is completed and placed in condition to produce. Each day's loss of producing time means reduced ultimate recovery in competition with other earlier drilled or more constantly operated wells.

Proration usually tends to reduce the advantage of the earlier drilled well by restricting more drastically the highly productive wells and preventing them from unduly depleting the reservoir pressure before other wells can be drilled and brought into competition. Yet the advantage of the early wells still persists in some degree, if only in the greater number of days or months of producing time. Proration systems based on well potentials encourage early drilling of wells, for only when wells have been drilled and their potentials established, will the operator be permitted to compete equitably with his neighbors.

Some of the most striking examples of loss in initial and ultimate productions are to be found in the production records of unrestricted gas drive fields. Comparisons of the rates of decline and ultimate productions of offset wells in the Coalinga and Midway fields of California provide ample proof of the disadvantages of delayed development. Complete production records over a period of years, sufficient to estimate closely their ultimate productions, were available for each of several hundred individual wells. It all cases where wells were properly completed and were producing under closely comparable conditions, the greater recoveries procured from the earlier drilled wells stand out in striking contrast with the relatively small recoveries obtained from the later drilled wells.

Fig. 1 presents the production records of a typical group of wells. Here, it will be observed, Well No. 1 was drilled one month before No. 2 and No. 3 seven months later than No. 2.

"Hughesite" . . . Armor for a front-line fighter

The Oil Well Drilling Industry is relentlessly driven by its desire to meet the demands of war. With Victory so dependent on this vital fluid, no other wartime task is greater.

Hughes specialized drilling tools are front-line fighters in this battle for production. They are war products for a war industry, and, as such, are built to stand the strain. Hard-faced with "Hughesite", a tungsten carbide of exceptional hardness and density, the teeth of Hughes Rock Bits provide the ultimate in wear-resistance . . . for better performance . . . for quicker Victory.

Well No. 1 had the highest initial production of the group and has an indicated ultimate production 1.55 times that of No. 2 and 2.64 times that of No. 3. The production of Well No. 2 is 1.7 times that of No. 3. After the wells enter upon the period of settled production, their rates of production are roughly equivalent. The great advantage of the early wells is found in their production without offset competition during the early period of flush production. Delayed development results not only in loss of oil by uncontested drainage to earlier drilled wells, but in less efficient drainage of residual oil due to loss of formation energy as a result of gas drainage to earlier wells. The operator who fails to maintain the pace set by his neighbors in the drilling of wells, not only loses some of his oil to his more active neighbors, but also leaves oil in the ground, gas-drained and without motivating energy, which neither he nor his neighbors can procure, except perhaps by applications of secondary recovery methods at higher costs.

C. A. Warner* points out that under usual leasing provisions, there is an expressed or implied obligation on the part of the lessee to protect oil producing properties against drainage to wells on neighboring properties by drilling offset wells within a reasonable time. The lessor may seek damages by litigation unless the lessee displays proper diligence in meeting this obligation. Warner proposes a geometrical solution for the damage suffered by failure to offset, in which the loss suffered by the later drilled well is considered to be that proportion of the production of the earlier well, prior to completion of the later well, that the acreage tributary to the later drilled well bears to the acreage tributary to the earlier well during its period of uncontested production. Such a solution is admittedly an arbitrary one and ignores several factors that may materially influence the drainage suffered.

Application of the pressure-maintenance method of oil field exploitation in a gas drive field modifies to a considerable degree the advantages normally enjoyed by the early wells. When field pressure is substantially maintained by reinjection of surplus gas into the reservoir rock at the crest of the structure, the initial productions of later wells will be comparable with those of earlier wells. The viscosity of the residual oil in the reservoir rock is changed but little by the drainage influence of the earlier wells. The later drilled wells must suffer some loss in ultimate recovery in comparison with the earlier wells, however, by reason of the shorter period of production time available to them. A field operated by the pressure-maintenance method is comparable with a water drive field, insofar as the influence of the time factor on production economics is concerned.

Aside from considerations of drainage, late drilling of wells means economic loss to their owners because of the loss of interest that might have been derived from profits on earlier drilled wells. Money in the bank earns interest; oil in the ground not only earns no profits, but actually occasions loss through taxation and carrying charges. The interest cost of deferred production will partially be offset by the deferred interest charges on development and operating expenditures. These and other related economic factors of importance in oil field development have been discussed in an earlier article of this series in their relation to well spacing, and need not be reconsidered here although they apply with equal force in determining the time at which wells may be drilled most profitably.

Other factors than drainage and interest loss may have an important influence in determining the time when wells may most profitably be drilled. Questions of market outlet and selling price of the oil and gas are, of course, of vital importance. The foregoing discussion has assumed that market outlets could be found for substantial production during the early life of a field and that overproduction would not depress prices; but the reverse is often the case. Time is necessary to provide pipe line outlets for substantial production from a new field; purchasers may not be immediately at hand and ready to absorb the large amounts of oil and gas resulting from many wells in flush production. Production in excess of needs of the tributary market will require storage of oil and perhaps waste of gas, both of which mean economic loss.

Another important consideration with many operators is the availability of capital with which to drill early wells in a new field. Until the potentialities of a prospective area are determined, drilling expenditures present greater financial hazards. Until field limits are determined, there is always the possibility that a costly edge well will be found dry. Some operators prefer to let others do the pioneer work of blocking out productive acreage before planning development programs for their own properties. Bank officials are often reluctant to lend capital for the development of outlying properties in new fields, and operators are compelled to adopt a conservative drilling program in which the profits on production of early wells may contribute capital for the drilling of later wells. Indeed, the early, simultaneous drilling of all wells on a property, which from some points of view would be theoretically most advantageous, is seldom feasible. Some of the wells on a property of considerable size must of necessity be later drilled wells, but the intelligent operator will so plan his operations that these will be

*"A Solution to the Problem of Damage Sustained Through Off-set Drainage," C. A. Warner. *Mining and Metallurgy*, August, 1931, pp. 357-359.

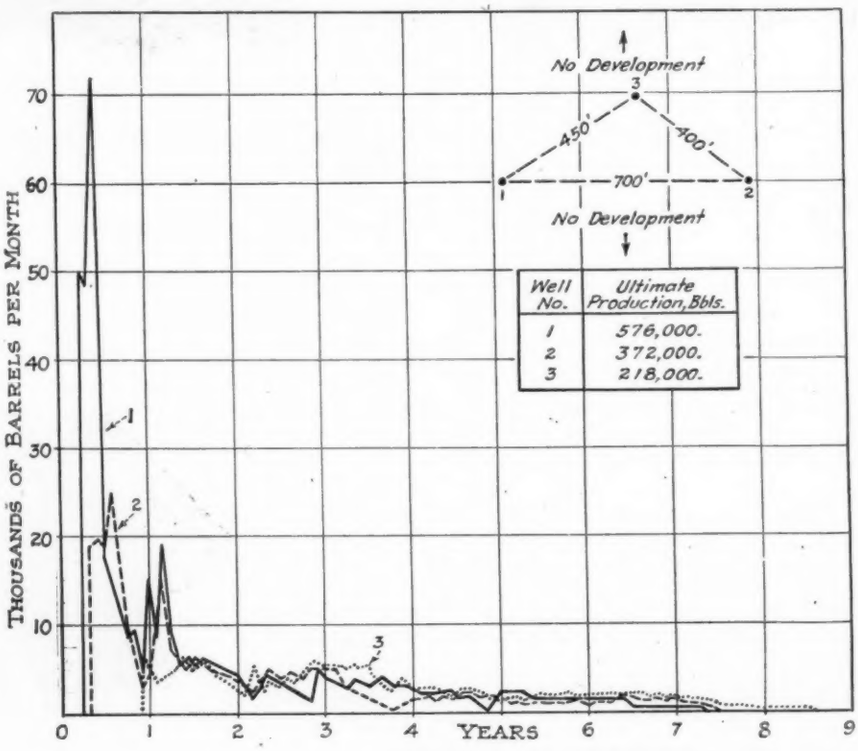


Fig. 1. Production records of an isolated group of three wells in the Coalinga field, California, illustrating the economic advantage of early drilling

WITH MISSION VALVES
you get
LONGER, UNINTERRUPTED PERFORMANCE

NEW VALVE INSERTS last at least twice as long as regular inserts
(COMPOUND 308)

Actual field runs show that Compound-308 Inserts last far longer than regular inserts in ordinary mud and many times longer than regular oil resisting inserts when hot, oily, or chemically treated mud is pumped.

"CHANGE THE BUSHING AND SAVE THE SEAT"

This low cost replaceable bushing takes the wear instead of the valve seat. Longer valve seat life results in less shut-down time and low replacement cost.

Field pump use has proved the superiority of Mission Slush Pump Valves so consistently that we can guarantee them to be the most economical valves on the market to use.

•

Thousands of operators all over the world have found that Mission Slush Pump Valves speed up drilling by improving slush pump performance.

Use all
MISSION PUMP PARTS
They work together for best all round performance

Mission
MANUFACTURING CO.
HUMBLE ROAD HOUSTON, TEXAS

interior locations in areas that will suffer as little drainage as possible to earlier drilled wells.

Life of Properties

An important consideration in planning the development program for an oil producing property, is the determination of the period of time within which the tract may be drained of its economically producible oil and gas with maximum profit. During recent years, proration restrictions have deprived the operator to some extent of the freedom of action that he previously enjoyed in adjusting the rate of production of his property to that which would result in maximum profit; but this is perhaps a passing phase in the history of the American petroleum industry. In any case, it would seem to be the obligation of some one—either the producer or the proration authority—to determine the most economic rate of exploration for each individual property and field.

Within limits, the operator may determine the time of exploitation of his property: (a) by the number of wells drilled thereon; (b) by the rate at which they are permitted to produce and (c) by the method or system or exploitation adopted. Determination of these factors will largely control the drainage efficiency and unit production cost. The remaining economic determinant, the selling price of the product, is generally beyond the control of the individual producer, yet even this may locally be influenced adversely by adoption of a development program and methods of field exploitation that result in production in excess of market needs.

As has been explained in an earlier article of this series, close spacing of wells permits of rapid recovery of the producible oil. This is true, both in gas drive and water drive fields. Drilling of many wells on a property in a field where production is competitive and unrestricted, permits that tract to produce a greater share of the field's oil than it would produce with fewer wells, and results in more rapid depletion, thus increasing the ultimate revenue derived from the property, and its present value. Excessive costs incurred in drilling and operating the many wells necessary in such a program would result in higher costs, however, perhaps yielding a smaller overall profit than could be obtained with fewer wells, requiring a longer time to deplete the property.

Development expense is but a part of production cost. The cost of operating wells and of handling oil and gas after they reach the surface are important elements of production cost. Unit operating and production costs increase rapidly as the rate of production of wells diminishes. Unit operating costs are usually higher in the case of closely spaced wells than with widely spaced wells because of the smaller per-well rate of production: a condition that becomes critical toward the end of the economic life of the property when operating cost gradually approaches and eventually overtakes selling price. Small economies in operating cost or moderate increase in selling price of the product toward the end of the productive life of the wells will operate to materially extend the economic life of the property.

Continued operation of marginal, stripper wells presents one of the important economic problems of the American petroleum industry. Conservation of our remaining petroleum resources should dictate a policy of price stabilization at a level that will make it profitable to operate such wells as long as possible. An alternate plan of taxing flush production in new fields to subsidize stripper production in marginal fields might be equally effective.

Application of water flooding, gas injection, or mining methods of procuring a second "crop" of oil from fields depleted, so far as primary methods of recovery are concerned, affords a practical means of extending the economic life of oil producing properties. Such methods, however, are commercially profitable only with a price structure somewhat higher than that which has existed in recent years. In view of the probability of higher oil prices during future years, no estimate of the economic life of an oil producing property is complete without taking into account the possibility of operation by secondary recovery methods when continued operation by primary methods is no longer profitable.

Efficient Production Rate

There is for every oil producing property, a certain optimum rate of production at which maximum profit will be achieved. This is not necessarily the rate that will result in maximum recovery efficiency. Determination of the optimum rate for most profitable operation must take economic considerations into account. In determining the optimum rate for maximum oil recovery, consideration is given only to physical factors governing drainage. Naturally, the oil producer's interest attaches to the former rate rather than the latter. The consumer and the conservationist on the other hand, are concerned primarily in promoting conditions that will assure maximum oil recovery. Thus, the interests of the producer are at variance with those of the consumer and the public, except that the consuming public is interested in keeping the producer in business. The public interest requires that the producer shall realize profit on his operations, but not necessarily the largest possible profit.

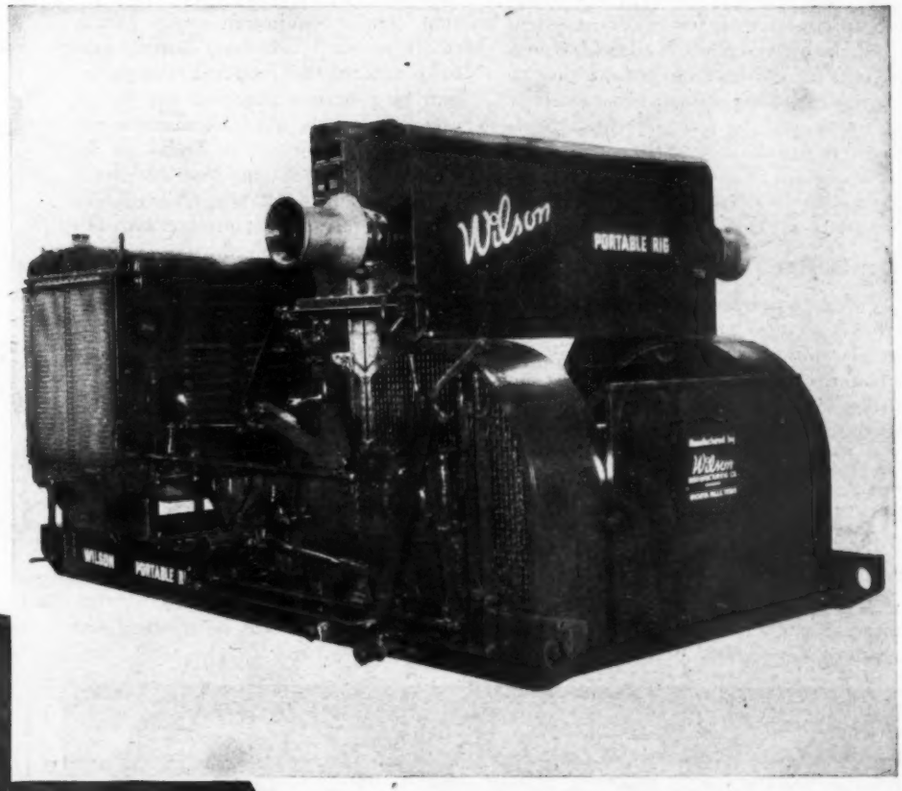
It must be confessed that petroleum technologists have not yet devised a means of determining with precision, either the optimum rate for maximum profit or the optimum rate for maximum recovery. Because of the difficulty of evaluating certain intangible factors involved in such computations, present methods result in what are at best mere approximations. In water drive fields the maximum permissible rate of production for a field may be that which will allow edge water to encroach as rapidly as fluids are withdrawn, thus avoiding serious loss of reservoir pressure and release of gas from solution in the oil. Or, perhaps the rate of recovery will be that which, it is assumed, will prevent irregular infiltration of edge water into the reservoir rock and trapping of bodies of undrained oil in the less permeable strata or lenses. In gas drive fields it is sometimes assumed that the most efficient rate of production for maximum recovery is that which will result in a minimum gas-oil ratio. If this rate is too low to be economically attractive, the producer may compromise by adopting a certain higher rate that will achieve reasonable production efficiency and profit.

For each well, at a given time, there is a certain ratio existing between the rates of gas flow and oil flow through the reservoir rock into the well that will result in maximum efficiency in oil recovery; but this is not constant and it will vary as drainage proceeds and with change in the relative amounts of gas and oil in the pore spaces of the reservoir rock. Obviously, such a ratio will vary widely for different wells and in different areas in the field. Determination of this most efficient rate involves analysis of a variety of complex variables, the evaluation and formulation of which presents many difficulties.

Proration authorities and agencies charged with production control in the petroleum industry glibly state that a certain field, property, or well has a certain maximum efficient rate of production, but investigation will generally disclose that there is little more involved in the determination of this rate than a few arbitrary assumptions that will not stand scientific scrutiny. There is a great need for development of more dependable methods of determining the maximum efficient rate of production. Doubtless, in many instances, proration authorities are led by considerations of restricted market outlet to impose upon producers rates of production that are clearly below the most efficient rate. Conversely, in time of oil shortage, as at present, pressure may be exerted on the operator to produce his oil at too rapid a rate for best results. Thus the

ON *Winches that Fight*

THE BEARINGS ARE SKF'S



● *Built by*
WILSON MFG. CO., INC.

Now is not the time for oil field machinery to relax . . . to slow down the flow of precious oil to where it's needed most. It's the time for sturdy, well-built machines like this Wilson Winch that's equipped with SKF Spherical Roller Bearings. It's the time for high load carrying capacity, self-aligning characteristics and smooth-running of SKF's that often make the difference between downtime and fulltime production. A machine that depends upon SKF Bearings can do much more to end the War quickly and successfully. 5391

SKF INDUSTRIES, INC., PHILA., PA.

producer is compelled to pattern his operations to a prescription that he knows will result in loss in ultimate recovery or reduction in the profit that he might otherwise realize in the exploitation of his property.

There would seem to be no apparent remedy for this difficulty under present proration practices. Perhaps when surplus productive capacity exists, a system could be derived wherein all fields would be entirely shut in from time to time to permit each to operate at other times at its most efficient rate. Or, flush fields could in turn be shut in for such periods as would adjust overall output to market needs, yet permit each field to operate at its most efficient rate.

Conclusion

In this article, it has been shown that time is a factor of primary importance in planning the exploitation of an oil producing property. Wells must be drilled at a suitable time in relation to surrounding development, otherwise the owner of the tract on which they are situated will suffer an irreparable loss. In gas drive fields, later drilled wells characteristically display smaller initial and ultimate recoveries than do the early wells in the same locality. In water drive fields, the later drilled wells suffer a loss in ultimate recovery, but not necessarily in the initial rate of production. These conclusions apply particularly to uninfluenced, competitive fields and may be modified to some extent by proration practices and by application of the pressure-maintenance method of exploitation. Delay in development may also occasion additional loss as a result of deferred realization of profit on oil and gas production. The market demand and selling price of oil may dictate the exploitation program, compelling a slower rate of development than other considerations might require. Lack of available capital for rapid early development of producing properties is responsible for delay with many operators.

Determination of the economic life of an oil producing property is an important problem that confronts every oil producer. This problem presents both physical and economic factors, some of which are intangible or susceptible only of approximate determination. Higher oil prices, reduction in production cost, and application of more efficient recovery methods will operate to extend the economic life of oil producing properties. For every oil producing property, there is a certain optimum rate of production that will result in maximum profit, but this is not usually the rate at which maximum recovery will be achieved. A technically satisfactory means of determining the most efficient rate of oil production under a given set of conditions remains to be determined. It is believed that rates of production prescribed by proration authorities often fail to coincide with the optimum rate for most profitable operation.

—— ☆ ☆ ☆ ——

P 778.4

Tanks and Containers for Gas

AN interesting example of the thousands of fabricated tanks and containers being turned out by modern arc welding methods is described by the manufacturers, Eaton Metal Products Company, Denver, Colorado, in a recent account submitted to The Lincoln Electric Company, Cleveland, Ohio, producers of arc welding equipment.

Fig. 1. Operator welding a cylinder head to tank proper

The method of constructing the gas tanks is extremely simple, requiring minimum time and effort.

The cylinders comprising the tank bodies are of mild steel sheet, 3/16 in. to ⅜ in. in thickness and formed in one, two, or three pieces, depending upon whether the unit is of 24 in. or 48 in. diameter. The pieces are butted together and welded at the seam, using single pass both inside and out.

An inlet and outlet vent for the tank consisting of a length of 2½ in. diameter pipe is next welded at both the inside and outside joints to assure a tight seam.

The tank end pieces or heads are of ¼ in. to ½ in. steel, formed at the edges to conform to the circumference of the cylinder. Fig. 1 shows the operator completing the welding of a cylinder head to the tank proper. On heads having a thickness of 5/16 in. or more, the edges are beveled slightly as shown at A in Fig. 2, so that sufficient penetration of the weld metal can be effected to form a strong, leak-proof seal of the joint.

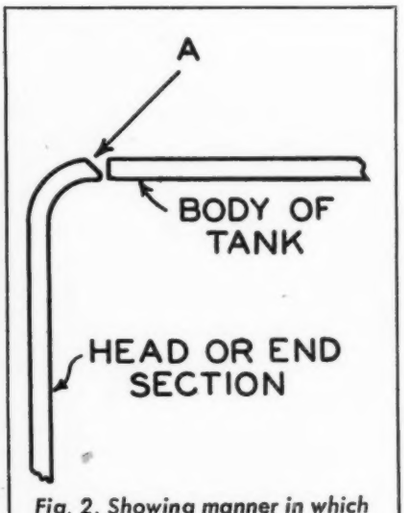


Fig. 2. Showing manner in which edges are beveled

In one of the heads for each tank, a ¾ in. flange is welded to serve as a drain for the tank.

Upon completion of the arc welding, each tank is subjected to a test in which air and soap suds are used to detect any possible leakage. The success of this method of fabricating and testing the gas tanks is evidenced in the finished products, which must withstand pressures up to 250 lb.

—— ☆ ☆ ☆ ——

OIL . . . from Earth to Air through KEROTEST VALVES

Fighting oil travels through Kerotest Valves from the well to the refinery, and throughout its processing into America's (and the world's) finest aircraft-quality gasolines. At every control point on the way, Kerotest Valves are doing a faultless job for all of us.

KEROTEST MANUFACTURING COMPANY
PITTSBURGH, PENNSYLVANIA

Central yards for reconditioning the pipe were never more than 15 miles from the right-of-way

Pipe Line Reconditioned, Flow Reversed

☆ Methods used to convert gas system to pumping of crude oil

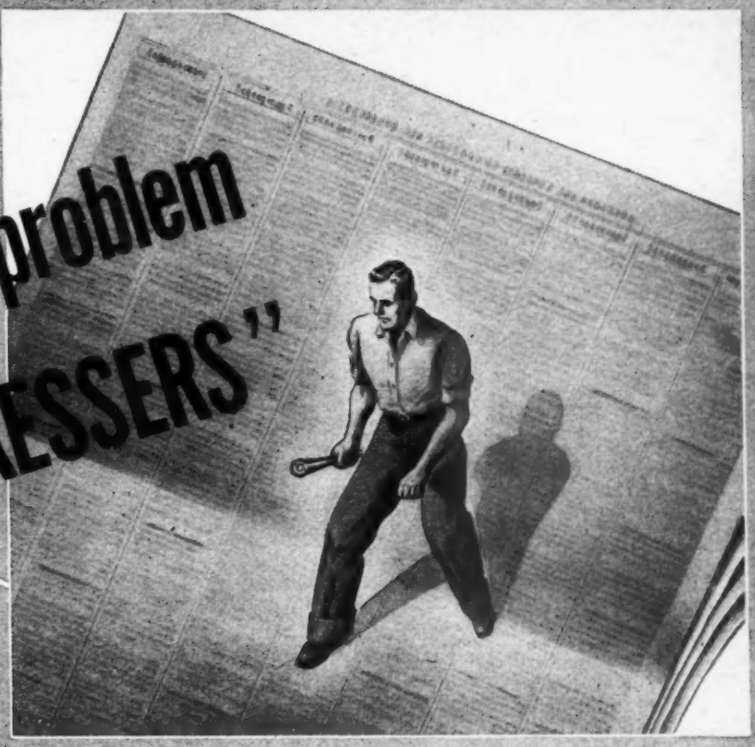
PETROLEUM ENGINEER Exclusive Feature

by Frank H. Love
Managing Editor

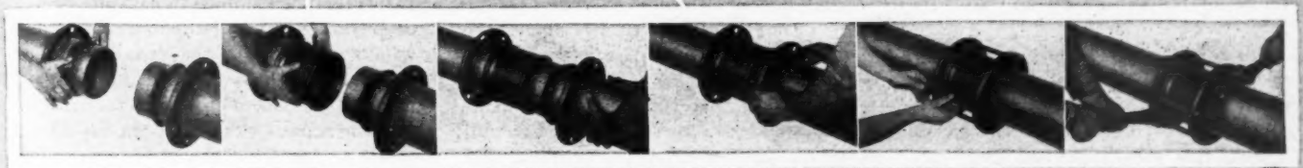
WHEN the "Big Inch" line from Longview, Texas, to the East was approved for construction it was realized that an enormous volume of crude oil would be required to supply this large diameter carrier. As a result several new feeder lines were laid and, because of the shortage of steel, a number of lines already in existence were converted to what was considered a more essential use. In the case of some of the latter it was necessary to reverse their flow. Such was true of the pipe line between Refugio and Pierce Junction, Texas, near Houston. This line was purchased by Defense Plant Corporation from the Houston-Gulf Gas Company. At the time of its acquisition it was delivering natural gas from Southwest Texas to the Houston-industrial area. Conversion to a crude oil carrier was done by Humble Pipe Line Company

The first step in taking up the line was to uncover the pipe with conventional type ditching machines

MAN POWER no problem with ready-made "DRESSERS"



Your newest workman can learn in a few minutes how to join pipe—right and tight—with efficient Dresser Couplings. No previous experience necessary. One man can install the smaller sizes. Two men can install any size. The only tool needed . . . a ratchet wrench.

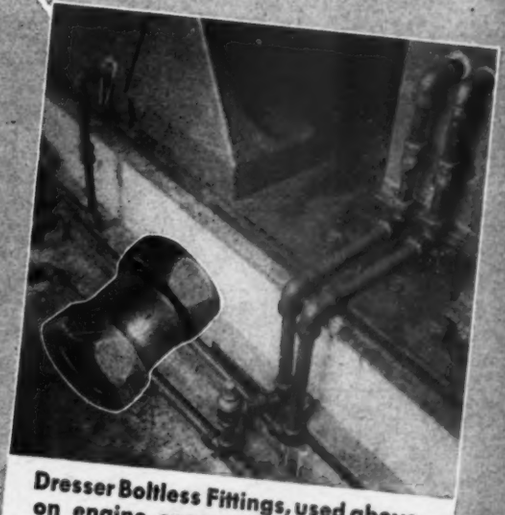


Speed, flexibility and skill are factory-built into these carefully engineered Couplings. Each Coupling is as strong or stronger than the pipe for which it is designed . . . absorbs expansion, contraction, deflection . . . remains tight for the life of the line. Installation time —about two man minutes per bolt.

Investigate Dresser advantages for your gas, water, oil, sewage or other lines, and for machinery and equipment settings. Day or night your pipe-joining work will go ahead fast with these time-proved mechanical "DRESSERS." Catalog 402BM on request.

Couplings, Fittings, Repair Clamps and Sleeves for practically all kinds and sizes of pipe.

Save Man Power with Dresser Couplings



Dresser Boltless Fittings, used above, on engine connections, come completely assembled. To install, slip over plain pipe-ends and tighten end nuts. Sizes, 3/8"—2" inclusive.

In Canada: Dresser Manufacturing Co., Ltd., 60 Front St., West, Toronto, Ont.

DRESSER MANUFACTURING COMPANY

AFFILIATED WITH DRESSER INDUSTRIES

BRADFORD, PENNSYLVANIA

This is typical of the electric stations on the line. Some stations had diesel engines for prime movers

(Photo courtesy Humble)

acting as agent for Defense Plant Corporation. Operation of the line is also by Humble as agent for Defense Supplies Corporation.

In addition to converting the Houston-Gulf line, Humble laid 21 miles of 12 in. connecting line from Pierce Junction to Houston, three miles of 12 in. line from Heard station at Refugio to the main line, and installed five pump stations.

At Houston the line ties into the Pan American Pipe Line, which transports the crude to Longview and the "Big Inch" system.

In addition to helping supply this system with its large daily requirements, the reversed line has the further utility of providing an outlet for the Corpus Christi area, which had had its production restricted because of reduced movement by tankers.

The line, which was originally laid with gasket type coupling sleeves, was first tested with water to determine the extent to which reconditioning would be necessary, and it was decided that complete reconditioning would be required for its operation at pressures necessary to pump oil.

Reconditioning Method

The method employed by contractors on the job to recondition the pipe is of interest. Conventional type ditching machines were employed to cut a trench to within 1 or 2 in. of the pipe. Two workmen equipped with cutting torches followed the ditcher, cutting the coupling sleeves. After the cuts were made a side-boom tractor was utilized to pull the pipe section from the coupling and lay it across the ditch. This was done in the following manner: the tractor hooked onto the coupling with its boom and shook the pipe loose from the small amount of earth that still covered it. With one end of the pipe raised a sling was placed around it. The tractor then backed up, picked up the sling, and pulled until the end slipped from the coupling. The joints were laid across the trench and later were loaded on trucks and hauled to a central yard for reconditioning. After the work was well under way trucks taking a load of pipe to the yard returned with a load of reconditioned pipe, making the procedure continuous and wasting no effort or facilities.

The central pipe yards were moved at specified intervals so that at no time was the haul to or from the right-of-way more than 15 miles.

Upon arrival at the yard the pipe was unloaded onto racks that extended the complete length of the yard. The initial operation was to run the pipe through stationary type cleaning machines for removal of dirt and rust. Two machines were provided at each yard for this purpose. Coming from the machines the ends were beveled and two joints of pipe tack welded into a 40 ft. length. Inspectors determined what pits were deep enough to justify spot welding and which portions of the pipe could be salvaged by halfsoling. These were marked for the welders. After such welding repairs were made the finishing welders completed the joints, the pipe then being moved along to the end of the pipe rack, which was approximately

The line was relaid by the stove-pipe method. Here a pipe joint is being lined up for the welders

Joint of pipe being pulled from the trench by a sideboom tractor *(Photo courtesy Humble)*

On some far off battlefront
Your Gaso Pump Is Making History

Here at last is the thrilling story of Gaso's part in World-War II — the explanation of what's happening to the Gaso Pumps which, in normal times, would have gone to you.

In this mechanized war, no army can advance faster than its supply of oil. And no problem facing our army is more important than that of assuring to our advancing forces an ample, continuous flow of the fuel upon which their mechanized equipment depends.

The problem has been solved with American ingenuity and enterprise, through the medium of portable pipe lines. Laid with incredible speed, ready for service immediately on completion, and maintained with a minimum of attention and manpower, these lines are helping to make history in every theater of war.

It has been Gaso's privilege to be the exclusive supplier of the pumps that give life to the lines that are moving ever closer to Berlin and Tokyo. We are grateful not only for the privilege but for the cooperation and sacrifice of our men, who have made possible a production schedule that we wouldn't even have dreamed about before Pearl Harbor . . . Gaso Pump & Burner Mfg. Co., 902 E. First Street, Tulsa, Oklahoma. Export Office: 149 Broadway, New York. Shreveport: W. L. Sommer Co., 419 Lake Street. Los Angeles: Service Oil Field Supply Co., 5333 S. Riverside Drive.

GASO PUMPS

FOR EVERY OIL INDUSTRY NEED

a quarter mile in length, ready to be hauled back to the right-of-way.

Relaying the Line

The pipe was relaid in the original ditch, surplus earth first being removed from the trench by a ditching machine.

The line was laid in the conventional manner. After joints were welded the pipe was left resting on skids above the ditch. A self-propelled cleaning machine with primer head attached operated behind the welders, followed by a traveling type coating and wrapping machine. In the cool of the morning when the pipe was at its maximum contraction the line was lowered into the ditch and backfilled.

Testing was by sections, a scraper first being run, the ends plugged, and air applied.

Prior to being welded into the line the pipe was graded and the heaviest used where pressures would be greatest.

From Refugio for a distance of 58.3 miles the pipe is 14 in. in diameter, the remaining 91.7 miles being 16 in., except for the Brazos and Colorado river crossings. Across the Brazos River two 10 in. lines were laid and across the Colorado River three 10 in. lines.

Five pumping stations were erected. At one station prime movers consist of three 400-hp. air induction diesel engines driving reciprocating pumps. At each of the other stations three 400-hp. electric motors driving centrifugal pumps are installed. At Houston terminal tankage was leased from The Texas Company, and at Heard station tankage was leased from the Atlantic Refining Company, Houston Oil Company, Humble Oil and Refining Company, and The Texas Company.

Initial operation of the converted line was with two stations on the line. With this equipment 50,000 bbl. of oil are being pumped daily. When all five stations are in operation the line's capacity will be 75,000 bbl. a day.

The line obtains its crude oil supply from the Atlantic, Barnsdall, Corpus Rosa, Humble, and Texas pipe lines, which have reversed established lines from the Corpus Christi and Ingleside areas for this purpose. In addition, crude is also received from other companies that gather directly into Refugio.

Williams Brothers Corporation was the contracting firm for the north end of the line and O. C. Whitaker Company for the south end. ——— ☆ ☆ ☆

Every possible joint of pipe was salvaged. Here can be seen several sections that have been half-soled

Coupling sleeves were severed by cutting torches to permit removal of pipe from trench

(Photo courtesy Humble)

Determining Size of Diesel Exhaust

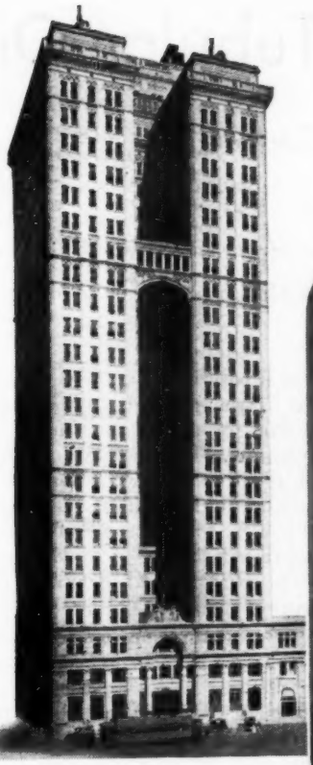
IF THE size of exhaust pipe of any engine is too small the efficiency of the engine suffers. A back pressure is built up that can seriously affect the capacity of the engine. Thus, for instance, when the writer was once operating a steam engine during the winter time in South Dakota the exhaust pipe became choked with ice. It was so cold that drippings that passed through the engine while it was hot in operation froze in the pipe that projected outdoors for a distance of about 5 ft. In other words, the pipe contained a solid "icicle" 4 ft. long. After starting up the next day the engine soon came to a stop because the exhaust steam couldn't get out. We wondered what was the matter and began looking around. Presently, after the hot steam began doing its work against the icicle and heating the projecting pipe, we heard an explosive sound and the engine started. That icicle shot out about 50 ft. and, of course, the exhaust steam was freed.

With the mounting importance of greater fuel economy and higher engine efficiency, the need for ample diameters is realized and considerable investigating has been done in that direction. As a result this writer has two rules:

For 2-cycle Diesels extract the square root of the horsepower of the engine and divide the result by 2. The answer is the diameter of the exhaust pipe in inches. Thus, for example, if it is a 100-hp., 2-cycle Diesel, the square root of 100 is 10. Dividing 10 by 2 we get 5 in. as the minimum pipe diameter for the exhaust. Likewise, going to the higher sizes, if it is a 3600-hp. Diesel the minimum diameter is 30 in.

For 4-cycle engines of the Diesel type extract the square root of the horsepower and multiply by 0.37. Thus, for example, if it is a 100-hp., 4-cycle Diesel the minimum pipe diameter for the exhaust is 3.7 in. If it is a 3600-hp. Diesel of the 4-cycle type this rule tells us that the exhaust pipe diameter must be at least 22.2 in.

In addition it is well to do everything possible to reduce gas friction by using few pipe bends, by avoiding a long pipe, and if a muffler is used see that it is of ample size. ——— ☆ ☆ ☆



Magnolia
Building
Dallas, Texas

20 YEARS IN DALLAS

Another Symbol of Stability

In January, 1924, Jarecki opened an office in the Magnolia Building, Dallas, Texas, and E. C. Munnell placed himself at the command of a vigorous and fast-growing section of the oil country.

Today the office is still functioning, and Mr. Munnell is completing a 20-year record of service — strong in experience, rich in friends and heartened by the knowledge that he is helping his customers carry on in the face of difficult wartime conditions.

Mr. Munnell is the kind of man you like to deal with — loyal, friendly, sincere. A veteran of World War I, he and Mrs. Munnell have two sons in World War II.

Both he and his record are living symbols of the stability that characterizes the Jarecki organization. It's a quality worth looking for when choosing a source of supply.

JARECKI

MANUFACTURING COMPANY

"Since 1852"

General Offices: St. Louis, Mo. Home Office and Factory: Erie, Pa., U.S.A. District Offices: Tulsa and Bartlesville, Okla.; Dallas and Houston, Texas; Mt. Pleasant, Mich.; Centralia, Ill.; Owensboro, Ky.

Branch Stores at All Important Places in the Oil Country

Modern Direct-Fired Tubular Oil Heater

PETROLEUM ENGINEER Exclusive Feature

PART 2 (Concluded)

by R. G. Lovell

Development Engineer, Hancock Oil Company of California

Oil Heater Furnace Design

IT should be recognized that the problem of furnace design for an oil heater contains factors that make it more complex and more difficult than the same problem for steam generation. These factors are the lower specific heat of oil, generally about one-half that of water, and certain processing demands. The latter, however, affect chiefly the distribution of the heat of combustion and do not change in any great degree the application of the fundamental principles of combustion. These factors, therefore, will be taken up later when distribution of furnace gases and oil in the tubes is under discussion.

Proposed Remedy

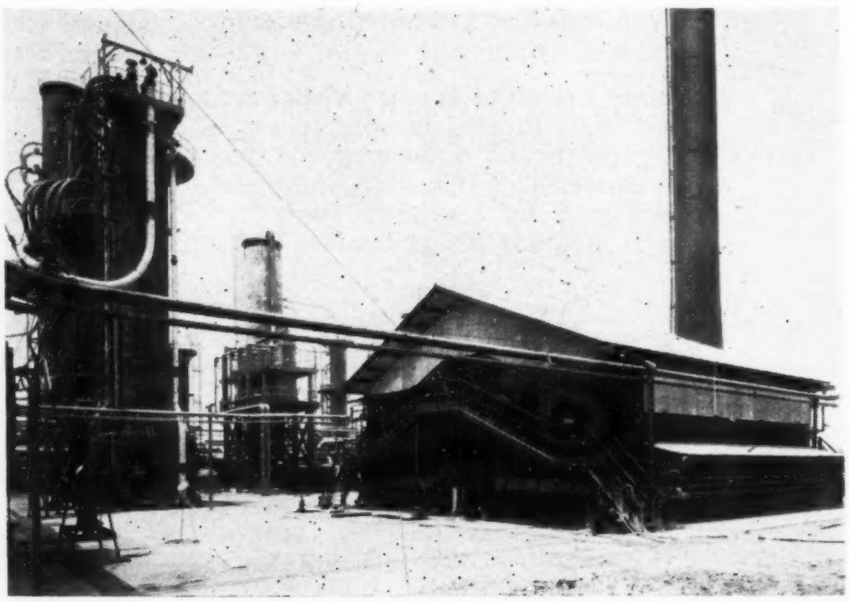
We propose now an idea for bringing complete combustion closer to perfect combustion and shall include an idea that is far from new, in fact it is one of the oldest—the dutch oven. We propose to use it, however, for an entirely different purpose from its previously conceived duty. The dutch oven has always been thought of as a device for accomplishing some part of the combustion ahead of the main body of the furnace and was used in just that way. It has been conceived as a saver of space, as it was expected to relieve the main furnace chamber of much of its combustion duty. Too much dependence was placed upon this theoretical function, however, and combustion chamber areas generally are still too small.

We point out that, if the dutch oven idea is adapted for use only as a mixer of air and fuel before ignition with sufficient area to accomplish that end, several very desirable results are likely to be had.

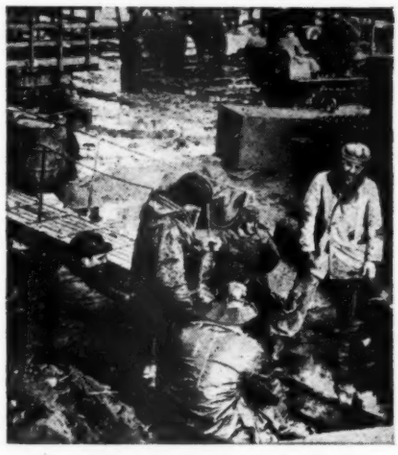
First, the mixture as it issues from the mixing chamber and encounters the heat necessary for ignition will be exactly what we want—a highly explosive gas. The form of expression "highly explosive" is an accurate description but is not intended to frighten anyone. Let it be understood that combustion in the furnace of an oil heater is basically the same chemical process as the gradual rusting of a piece of iron, or the explosion of a stick of dynamite. The only difference in physical effect is in the elements of time and space. Another and more familiar parallel can be found in the power cycle of an internal-combustion engine, either of the spark-ignited or the compression-ignition types.

The condition in our combustion chamber would be a constant flow of combustible gas into an area where, upon ignition, it releases an enormous amount of heat that, if confined, would generate pressure enough to destroy the furnace. The explosion of the stick of dynamite would cause no damage if it occurred, say, 300 ft. in the air. The difference in time element also finds an example in the dynamite simile. A stick of "fast" powder laid loosely on top of a rock and ignited still fractures the rock despite lack of confinement on three sides. This is explained by the speed of its combustion, which is so high that the pressure built up by the rock resistance is sufficient to cause fracture of the rock. Both time and space, then, enter into the calculation to determine what conditions we must offer this ignited mixture in order to realize its energy in the form of heat instead of pressure. Experience has shown that a furnace combustion area of 1 cu. ft. for each 15,000 B.t.u. per hr. released in the furnace does a fairly good job of combustion but it will be found that some modern and well-designed heaters provide from 2 to 3 times this space. This does not constitute an admission that the first figure is in error. The reason will be brought out shortly.

Second, the other and perhaps more important reason for seeking complete mixture of air and fuel before ignition concerns chiefly the heat transfer function of the heater unit. Reviewing some of the stages of development of tube heaters, which were presented in the article in the September, 1943, issue of *The Petroleum Engineer*, we find that we have been paying some heavy penalties in burned tubes for the false economy of inadequate combustion area. One of the factors that has retarded general acceptance of the principle of liberal combustion area has been our failure to realize that the stagnant film of furnace gases that surrounds a heater tube and acts as an insulator against transfer of heat by convection, offers no resistance to transfer of heat by radiance. The significance of this is mani-



Double end down draft heater. Capacity, 75,000,000 B.t.u. per hr.



"The pilots were quiet and solemn that night"...

Many tales have been told of men and tanks and planes. There is a story, too, of the drums of oil and gasoline that have gone with them to distant lands, and have played a part in strange adventures.

That story is told in "We Were There" — a modern odyssey that carries the reader through history-making exploits in Africa, the Pacific, Tunis, the Aleutians, Java and Alaska. It is profusely illustrated with original portraits of Winston Churchill, General Chiang Kai-shek, General Carl Spaatz, General Sir B. L. Montgomery, Lt. Col. Jimmy Devereux, and pencil studies of natives of Tunisia, the Aleutians and Java. A copy of the De Luxe Edition, beautifully bound, will be sent free upon request. Just mail the coupon.

De Luxe Bound Copy Free Upon Request

AMERICAN FLANGE & MANUFACTURING CO. INC.
30 Rockefeller Plaza, New York 20, N. Y.

Please send me, free of charge, a copy of the De Luxe Edition of "We Were There."

Name..... *Position*.....

Firm.....

Address.....

fest. We can proceed confidently to design and build combustion chambers that will be of such area as to approach high combustion efficiency and, at the same time, offer proper space for the release of pressures of combustion. Further, we can control the relative amounts of heat to be absorbed by radiation and by convection simply by providing ample stack height and giving more attention to damper control. Some of the leading manufacturers of refinery oil heaters now have this so well arranged that the velocity of gases in the radiant section is represented by a draft as low as 0.03 in. of water and at the same time provides properly higher velocities in the convection section.

Any reader who is interested in carrying his understanding of heater furnace combustion beyond the words-and-figures stage will find mental stimulus in carrying the internal-combustion engine comparison somewhat further, using each of four types of engine to throw additional light on the picture.

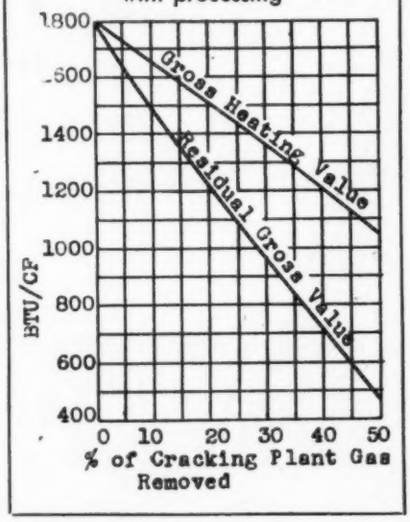
(1) Spark-ignited aspirated (not supercharged),
(2) Spark-ignited and supercharged,
(3) Semi-diesel (hot plate), and
(4) Full diesel (compression ignition).

Compared to Carbureted Engine

Virtually all mechanical men realize that one of the principal reasons for the low efficiency of the conventional automotive power plant is the fact that control of the air for atomizing the fuel, introducing it into the cylinders and then by combining with the fuel making the combustible mixture that provides the power, is a function entirely of the capacity of the engine to act as an air pump. In the operation of the unit driven by the engine, demand for maximum power comes at a time when the capacity of the engine as an air pump is at the minimum; that is, when the engine is at low speed. This is exactly the reverse of the desired condition. Ingenuity of designers of gear-ratio-change devices and of carburetors has improved this condition but cannot possibly correct it. The modern carburetor simply opens an additional jet to admit more fuel as power demand rises, but cannot inject additional air to burn the increased amount of fuel efficiently.

The parallel here would be in a furnace not provided with facilities for full control of air as the fuel is controlled. In the case of a gaseous fuel, control is usually obtained by pressure change ahead of the burner. Effect of increased pressure is to raise velocity through the burner opening, thus increasing fuel flow. Higher velocity of gas issuing from the burner tends to draw in more air through a given register opening but

Fig. 1. Reduction of heating value with processing



in nowhere nearly the additional amount required. The too-rich mixture is immediately ignited, expands and, unless offered adequate area for the expansion, develops pressure. The effect of the pressure is to increase the velocity of the gases leaving the combustion chamber. Higher velocity in the chamber tends to draw in more secondary air but, as in the case of the primary air, not nearly enough and certainly not at the right time and place. As previously pointed out, the secondary air, in mingling with the products of partial combustion, removes heat therefrom at the place and time we can least afford it. We certainly want maximum temperature in the radiant section of the heater in the interest of heat transfer per square foot of heat absorbing area. After having removed the amount of heat demanded by processing requirements in the radiant section we can then take the remainder, which is at a reduced temperature, over the bridgewall and through the convection section at the high velocity demanded for efficient transfer of heat by convection. If, however, we have been forced to use draft control to effect combustion, we will have lost control of heat distribution between radiant and convection coils. This would not be a particularly serious matter if the heater had but one simple duty, that of raising the temperature of a body of oil from an established low to a desired high, but it certainly is not a tolerable condition in modern processing, where the radiant and convection coils may each be performing a different duty.

Whereas the aspirated-carbureted gasoline engine was forced to choose the too-rich mixture in order to meet the peak power demand, the oil heater furnace was able theoretically to avoid the penalty of a too-rich mixture by using a combustion chamber large enough to allow for the introduction of additional air and its use in burning, with fair efficiency, the extra fuel. The writer's experience, however, has been that the larger combustion chamber existed more often in theory than in practice. Even when the larger combustion area actually existed, the evils of supplying secondary air during the combustion have still kept the heater, as a complete unit, from performing satisfactorily to meet modern processing requirements. The unit, when considered simply as a piece of equipment the sole duty of which is to extract the maximum number of B.t.u. from a unit of fuel and transfer the greatest practicable amount of this heat to the oil in the tubes, can show by standard tests a thermal efficiency greater than 80 percent, and still fall far short of fulfilling its full duty in the processing cycle.

Supercharged Engine Parallel

The obvious and proved remedy for the described weaknesses of the aspirated engine is supercharging and the obvious but not yet proved remedy for the combustion defects of a tubular oil heater may also be called supercharging. Just as supercharging a gasoline engine takes the air-fuel ratio out of control of engine speed and places it where it belongs —subject to power demand—so should the control of combustion air to a furnace be under the direct and accurate control of heat demand. The engine supercharger at least doubles the power available per cubic inch of cylinder displacement and does so by the simple expedient of replacing natural barometric conditions with an artificial pressure differential. Many refinery men have knowledge of the myriad difficulties that the supercharger had to overcome and knew that most of them were due to the fact that the engine was a high speed, mobile unit and, therefore, space and weight were factors of primary importance. In the case of the oil heater furnace the conditions are exactly opposite. The equipment is not required to move nor are space and weight of particular importance. Consequently, we have fewer difficulties to overcome than had proponents of engine supercharging.

Diesel Engine Comparison

Comparison of our problem with the power cycle of a 2-cycle diesel engine is interesting because it points up one of the details of furnace combustion that has been left largely to the imagination. Again, considerations of mobility enter the picture. In fact, these considerations had much to do with the development of the 2-cycle principle. In this type the burned gases are cleared from the cylinder by a blast of scavenging air supplied

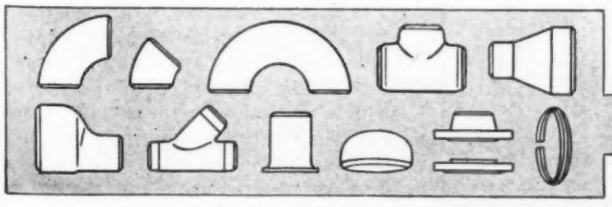
STRONG

The stress-strain machine, shown above in Tube Turns' laboratories, scientifically records tensile strength.

Welding fittings *must* be strong. Stronger than pipe. For the greatest strain and vibration occur *at the fittings.* Strength is imperative against the high pressures, extreme velocities and corrosive wear to which fittings are subjected in many piping systems. Strong welding fittings help to hold leakage, breakdowns and consequent repairs to a minimum.

Tube Turn's exclusive manufacturing process produces *extra* strong fittings. Tensile tests on the stress-strain recording machine methodically *insure* the superior strength standards found in all Tube-Turn seamless welding fittings.

TUBE TURNS (Inc.) Louisville, Kentucky. *Branch Offices:* New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Dayton, Washington, D. C., Houston, San Francisco, Seattle . . . Distributors located in principal cities.



TUBE-TURN
TRADE MARK
Welding Fittings and Flanges

by an auxiliary blower. Some of this air, at a very slight pressure above atmospheric, is trapped at the bottom end of the stroke and, when compressed by the succeeding stroke, forms the air to start combustion of the fuel that is forced in at the top of the stroke in a liquid state. From a check of figures given earlier in this article it will readily be seen that the amount of air necessary to complete the combustion of the fuel could not possibly enter the cylinder through a port of ordinary size in the short space of time the piston spends at stroke end. Nor could such an amount be supplied, at the necessarily high pressure demanded by the compression pressure, by an auxiliary compressor of reasonable size and weight. Therefore, a compromise is used whereby the air continues to enter the cylinder during a part of the power stroke. As the gases are then already partially burned the air must be supplied in quantities considerably in excess of the theoretical amount to insure fairly complete combustion of the fuel.

The need for this compromise does not exist in our heater furnace consideration. In fact, we can legitimately compare our objective with the power idea that has been the Utopian dream of engineers for a long time—the ignited gas turbine. Failure of metallurgical science to develop materials capable of withstanding the high temperatures involved and at the same time have strength to resist stress has been the retarding factor. When such metals have been found we shall have the ideal power unit.

Auxiliary Combustion Equipment

Throughout the entire history of petroleum refining there have been innumerable ideas advanced that at the time seemed to be panaceas for many of our troubles. Hardly more than 10 percent of them have survived and certainly not more than one-half of one percent hold their original form and purpose. Some of these ideas failed because they were wrong in concept or had major weaknesses in design or construction of equipment, but the greater part of those that failed to survive were entirely correct in theory and were well built, but did not meet with general acceptance for either or both of two reasons beyond their control. Sometimes their use simply pointed out better, but previously unconceived, methods of accomplishing the desired ends. In other words, they were casualties of progress. More often than not, however, it was found that the idea was sound technically but the cost to install and operate the equipment was not warranted by the additional product recovery or savings in fuel, or other facilities. There was no point in seeking justification for the idea if the only net result was a technical improvement in quality of product, unless the improved quality was to be reflected in better selling price. Many of the ideas also were used for some period of time, discarded and later picked up and put into service with marked success. Generally, changed processing requirements and market conditions justified the readoption of the idea.

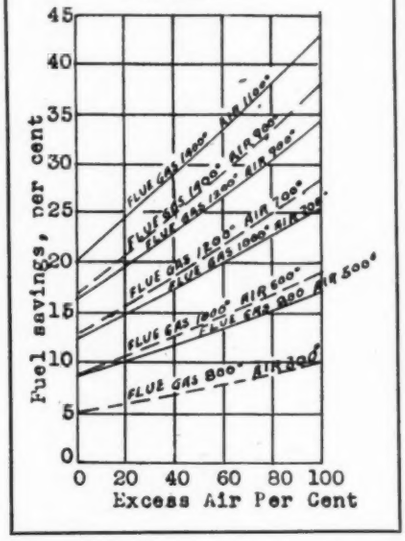
Flue Gas Recirculation

During the period of several years when we were concerned with the problem of tube failures in cracking plant heaters the scheme of forced recirculation of stack gases into the firebox became popular. It functioned by cooling the furnace gases before their impingement upon the radiant tubes and actually increased the rate of heat transfer in the convection section but reduced the B.t.u. absorbed per square foot in the radiant section. As our knowledge of heat transfer and combustion increased by experience, it was seen that there was no need to spend money for apparatus or power to drive it when the same end could be accomplished in an easier and less expensive way. Flue gas recirculation thus became another casualty of progress.

Preheated Combustion Air

The technical advantage of exchanging heat of stack gases for heat of combustion air is undeniable. In an oil refinery there are so many opportunities for exchanging product heat to incoming crude stocks that oil to heaters usually is at an elevated temperature that, although advantageous inasmuch as it reduces the amount of heat necessary to add in the heater, makes necessary a stack temperature higher than would be the case in other types of work, in order to maintain a decent rate of heat transfer in the later passes of the convection section. Before we had learned in the school of experience that this high temperature could be used to advantage for steam superheat, reboiler heat mediums, and other profitable ways, the idea of using this heat in the furnace seemed very attractive and came into widespread use in the larger plants. Flame temperatures were much higher with preheated air and this was generally conceived as being due entirely to the heat that had been added to it. It should be observed that the higher flame temperature is due as much to the greater facility with which a heated dry air mixes with the fuel and the consequent better mixture, of course, makes a hotter flame.

Fig. 2. Fuel savings due to preheated air



Preheated Air

We have become accustomed to the high heating value of cracking plant gas, about 1800 B.t.u. per cu. ft., and although many plants stabilize their pressure distillate, the primary objective of the stablizing operation has been to bring the vapor pressure in line with motor fuel specifications. In many cases the stabilizer cut has gone rather deeply into the C_4—butanes and butylenes—with the idea of bringing vapor pressure back into line again with blends of high vapor pressure natural gasoline, which, of course, helped to solve the sulphur problem by dilution. We now find ourselves confronted with the vital necessity of recovering from the crack-

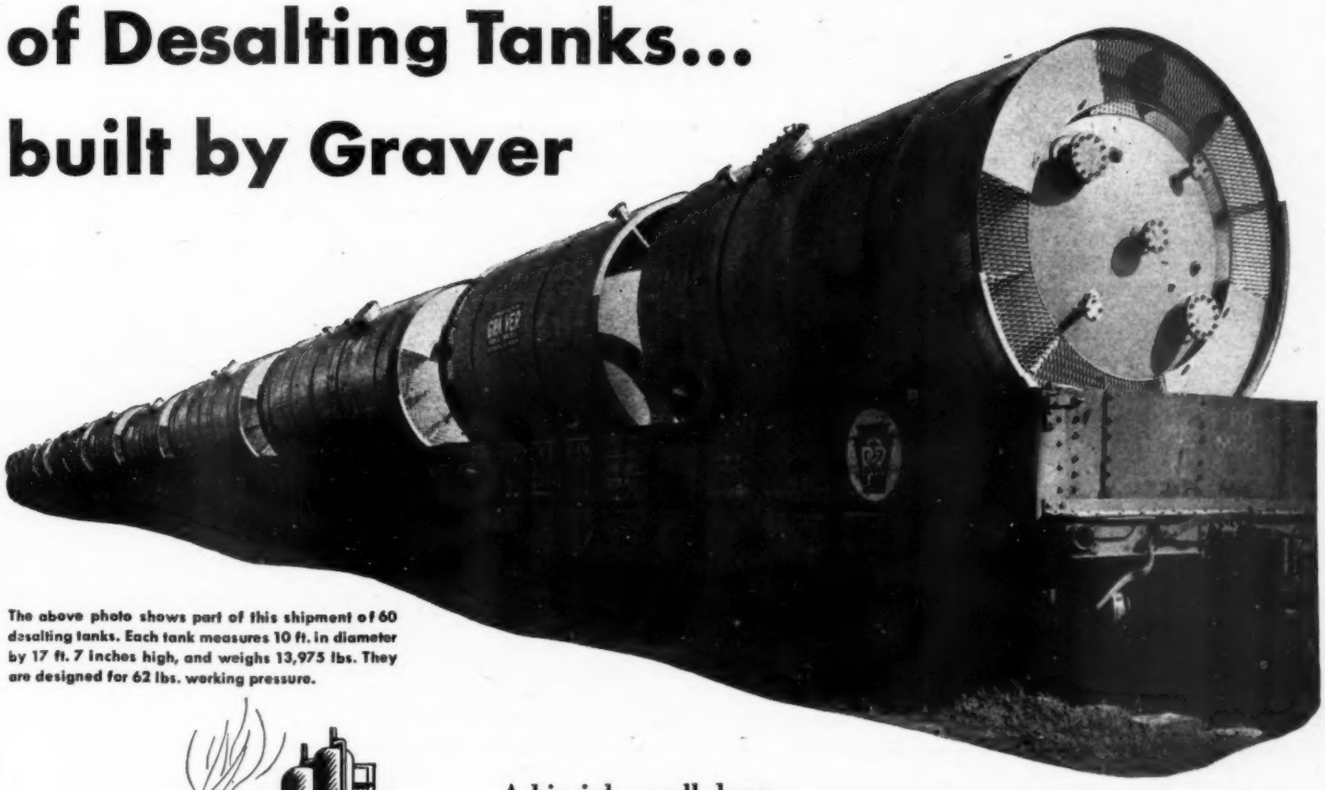
TABLE 2
Stack sizes for gas fuel

Stack dia., in.	Height in feet above furnace floor					
	80	90	100	120	140	160
33	7.5	9.5	10.7	12.4	14.1	14.5
36	9.6	11.6	13.6	15.2	16.7	17.8
39	11.5	13.9	15.8	18.4	19.7	21.5
42	13.6	16.5	18.5	21.8	24.0	25.6
48	18.4	22.4	25.3	29.7	32.8	35.0
54	23.9	29.2	33.1	39.0	42.9	46.0
60	30.2	36.8	42.0	49.4	54.9	58.9
66	37.4	45.7	52.1	61.3	68.1	73.3
72	45.1	55.5	63.2	74.5	83.1	89.2
84	63.2	73.0	88.9	105.5	117.8	127.3
96	84.3	104.0	119.0	142.0	158.8	172.0
108	108.9	134.3	154.0	184.0	206.2	223.9
120	140.8	168.4	193.5	231.8	260.4	282.9

Figures represent thousands of cubic feet of gas of 1100 B.t.u. heat value.

30 carloads

of Desalting Tanks... built by Graver



The above photo shows part of this shipment of 60 desalting tanks. Each tank measures 10 ft. in diameter by 17 ft. 7 inches high, and weighs 13,975 lbs. They are designed for 62 lbs. working pressure.

A big job—well done.

60 desalting tanks—30 carloads of them—on their way to speed up the production of petroleum products.

They're Graver-built—which means that they measure up to the most rigid specifications and will meet every requirement as to quality, performance, and cost.

Fabricating steel plate equipment for the Petroleum Industry is one of our most important activities. We have the equipment, the experience, and the trained personnel to handle any job, large or small. Your inquiry incurs no obligation.

GRAVER

FABRICATED STEEL PLATE EQUIPMENT

GRAVER TANK & MFG. CO., INC.

4811-61 Tod Ave., East Chicago, Ind.

NEW YORK CATASAUQUA, PA. CHICAGO TULSA

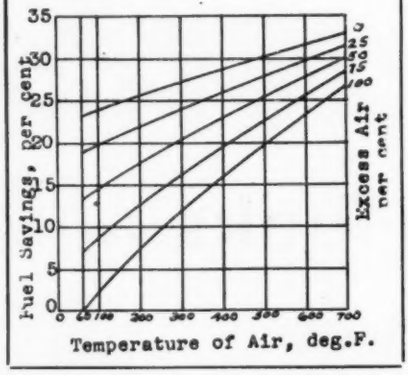
Expansion Roof Tanks Towers Pressure Vessels
Gasoline Storage Tanks Spheres Stills
Refinery Equipment

43-20-S

ing plant gases not only the C_4 but also the C_3, for use in reprocessing to produce high octane material for aviation gasoline and for butadiene manufacture for synthetic rubber. Nor are the high vapor pressure natural gasolines available for cut-back for the same reason. Not everyone realizes, however, how sharply the removal of these C_3 and C_4 cuts into the heating value of both cracking plant and natural gases. They comprise about 38 mol percent of a typical cracking plant gas and their heating value represents about 1000 B.t.u. per cu. ft. As this represents more than one-half the original heating value it certainly is a factor to be considered. Natural gas supplies to refineries, of course, suffer a comparable reduction in heating value. Fig. 1 will be found useful in estimating losses in heating value by various volume subtractions of propane and butane or their companion unsaturates.

It will be obvious that, in furnaces of heaters wherein large volumes of excess air must be used for any reason, the advantage in fuel savings to be effected by preheated air will be more marked than in units where the combustion can be accomplished by more reasonable amounts of excess air. When the heat content of a gaseous fuel has been markedly reduced, obviously, we must admit a greater volume of the fuel into the firebox. The seeming logical companion move is to admit a correspondingly greater amount of air. Let us examine the situation, however, and see whether this is the right thing to do.

Fig. 3. Effect of preheated and excess air on fuel savings. Flue gas temperature, 1070°F.



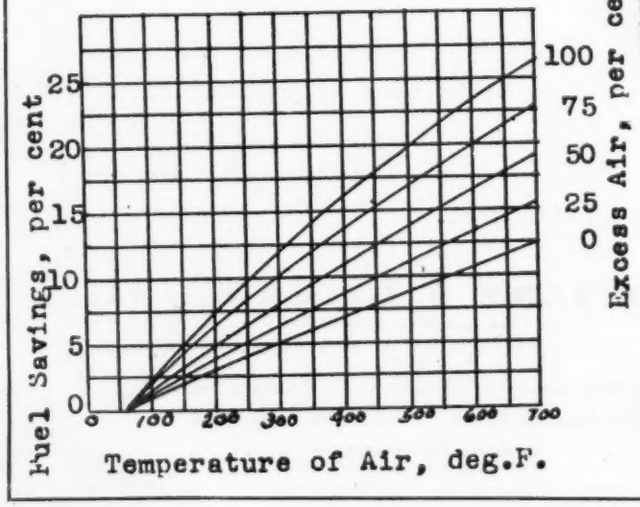
As the reduction in heat content has been made by removing the heavier constituents of the gas—those molecules containing the greater number of carbon atoms—the gas will require a smaller volume of excess air per unit of its own volume than with the full gas. It follows, also, that the flame temperature will be lower for the same reason and that, consequently, an increase in either or both the primary and/or the secondary air must reduce the amount of heat liberated in the combustion chamber thus reducing heater output.

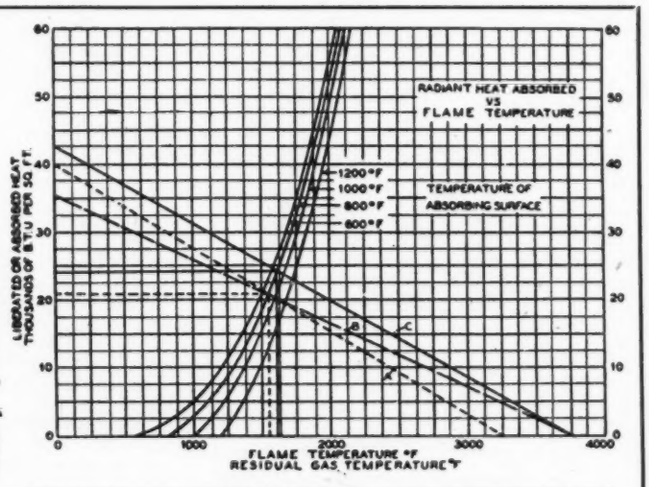
If, now, we preheat the air for combustion and, in addition, provide such means that the greater part of the preheated air can enter with the fuel, we have increased the flame temperature and reduced the excess air necessary to use and also provided for approximately the same heat liberation as with the full gas. Needless to say, the fuel savings compared with air of atmospheric temperature and with lean gas are sure to be substantial. Figs. 2, 3, and 4 will be found interesting in this respect.

A pertinent question is as follows: Does the amount of heat added to the air equal the reduced total of heat liberated because of the smaller amount of fuel burned? The answer is no. The heat liberation per square foot of tube area is lower for a given capacity of heater with preheat than without, but this does not mean that the fuel saving is only theoretical. Remember that the flame temperature is higher with the preheated air and there is, therefore, an increase in radiant heat absorption rate that is almost equal to the decrease due to lower heat liberation. The outstanding advantage of preheated air is in the fact that by its judicious use the total capacity of a heater can be materially increased over cold-air firing, provided of course the increase will not over-load the radiant-heat-absorbing surfaces that will be affected most by the increase. Higher amounts of liberated heat obtained at the higher capacity and the higher flame temperature obtained with preheated air will have an accumulative effect, so that the radiant heat transfer rates will increase almost in proportion to the increase in capacity. The convection heat transfer rates are changed very little with air preheat, within the range of capacity increase that is safe for the radiant heat absorbing surfaces. (See Fig. 5.)

Fig. 4. (Below) Fuel savings with preheated air for various air temperatures and excess air used—flue gas temperature, 1070°F.

Fig. 5. (Right) Radiant heat absorbed vs. flame temperature





Examples	A	B	C
	No air preheat	Preheated-air temperature, 660° F. heater capacity same as A	Preheated-air temperature, 660° F. heater capacity increased 15 per cent
Flame temperature, °F	3,250	3,750	3,750
Liberated heat per sq. ft. of equivalent effective surface, B.t.u	40,000	36,000	42,500
Temperature of heat-absorbing surface, °F.	800	800	800
Absorbed radiant heat per sq. ft. of equivalent effective surface, B.t.u	21,000	21,000	24,000
Residual temperature of gases, °F	1,550	1,550	1,580

CHECKING ALIGNMENT IN OUR SHOPS

TO SAVE YOUR TIME IN ERECTION

Misalignment and dimensional variation in piping subassemblies delivered to the job can cause considerable trouble and expense . . . and much lost time in field erection. It is a nuisance you need not tolerate.

Midwest takes no chances in this important matter. Every pre-fabricated subassembly is checked for dimension and alignment with utmost care. Any inaccuracies which this check discloses are corrected before shipment is permitted. As a result, Midwest Pre-Fabricated Piping is erected easily and rapidly.

Other time-saving and trouble-saving advantages of Piping by Midwest are the thorough cleaning to remove all scale, dirt, etc. before shipment . . . and the most careful inspection and shop testing.

* * *

Midwest Piping Service can be used to advantage whenever you need piping . . . whether a simple pipe bend or a complex high pressure piping job. Three modern fabricating plants are strategically located to serve you . . . and an experienced Erecting Division will take full responsibility for a complete piping installation.

MIDWEST

MIDWEST PIPING & SUPPLY CO., Inc.

Main Office: 1450 South Second St., St. Louis, Mo.
Plants: St. Louis, Passaic (N. J.) and Los Angeles

Sales Offices: Chicago—645 Marquette Bldg. • Houston—229 Shell Bldg. • Los Angeles—520 Anderson St. • New York—(Eastern Division 30) Church St. • Tulsa—533 Mayo Bldg.

Liquid Fuel

In the foregoing analysis of combustion in the heater furnace, major attention has been given to gaseous fuel, as it has been in plentiful supply and offered several advantages over liquid fuel. For reasons that have herein been given, all signs now point to greater use of liquid fuel. Previous articles in this series also have indicated that there is every reason to anticipate an active market demand for the lighter grades of bottoms fuels. The refiner will, obviously, seek methods whereby he can use the stocks with lowest sale value, but he must realize that in order to make this gain in revenue he must invest something in additional equipment if the inherently high heat content of the processing bottoms rejects are to be put to profitable use. The heat content is inherently high for reasons that are natural and easy to understand. Many of the processes through which the oil has gone have been of the general nature of destructive distillation with the objective of rearranging the molecular structure of the oil so that the recovered products would have better combustion characteristics when used in high compression internal-combustion engines.

In this molecular shuffle some of the hydrogen atoms are sure to end up in the discard but do unite themselves with other molecules and pass out of the cycle with the overhead gas when the distillate is stabilized. In attaching themselves to these molecules they have deformed the normal molecule and, in so doing, have given to them certain very desirable characteristics required for further synthesis. The bottoms, then, are bound to be short some hydrogen and, consequently, their molecules also are deformed, being predominantly carbon. The physical characteristics of the bottoms also have been changed in some considerable degree. This is evidenced by the changed viscosity-gravity relationship from a bottoms of straight-run distillation. Depending upon processing conditions, there is likely also to be some amount of coke, so fine in particle size that it remains in suspension.

The foregoing indicates that there are three major demands to be met, so that heavy liquid fuel can be used efficiently:

(1) Heat added to fuel.

(2) Efficient atomizing.

(3) Adequate combustion air.

It is obvious that, whereas the mixing of fuel and air in the case of a gaseous fuel is not particularly difficult, the liquid fuel must be caused to offer comparable facility if the mixing is to be accomplished with comparable thoroughness. The method used of necessity must be a compromise as the cost of bringing about equal facility would be greater than the advantages to be gained by use of the heavier liquid fuel. Atomizing is simply a rough, or preliminary, vaporizing. The liquid fuel could be fairly well vaporized by use of a sufficient amount of heat at high temperature but, at best, the vaporization would not be entirely complete and the heavy slugs and suspended coke would offer much trouble if the oil were at high temperature and consequent low viscosity. To avoid as much of this trouble as we can we shall dismiss the idea of using the system of oil burning generally used in marine work wherein the oil is heated in a closed heater under pressure to a temperature high enough to cause it to vaporize as it leaves the burner without use of an atomizing agent, such as steam. We have given the best of our fuel to the seamen and, for that very reason, we must decline use of their burning methods.

Atomizing with Air

Having decided upon outside atomizing little time need be used in selecting the atomizing agent. Realization that the heat to generate steam for this purpose usually represents about 3 percent of the heat liberated by the combustion of the atomized fuel, has given rise many times to the idea of using compressed air as the atomizing agent. In cases where a shortage of steam generating facilities existed and an adequate supply of compressed air was available, power to produce it coming from sources other than steam, the idea appeared to have merit. Theoretically, also, there seemed to be some justification inasmuch as the air would serve as an aid to efficient combustion, particularly because of the intimacy of its contact with the fuel. The latter is unquestionably true but its advantage is outweighed by the low temperature of the air when reexpanded, due to necessary removal of heat of compression, and the inevitable entrapment of slugs of water. In light of the many sources of waste heat in a refinery, however, it might be interesting to pick up the idea again and give it further consideration with the thought of replacing the lost heat of compression with some of the waste heat.

Atomizing with Steam

There is seldom any trouble encountered with steam but a more complete consideration of the manner in which it functions might lead to some improvements in utilization methods. There are several interesting theories that enter into a discussion of this matter but not all of them can be turned into realities for sound functional reasons. For example, a refinery operator immediately thinks of the manner in which steam performs in the distillation process and endeavors to set up a parallel function in atomizing fuel oil. Failure of practice to line up with theory here is in the element of time. The action of steam in accelerating the boiling, or vaporizing, of the oil is founded upon certain well-known laws of chemical science having to do with partial vapor pressures and requires that the oil be stationary or moving at a low velocity and that the pressure upon it be low. Obviously, these conditions cannot be attained in the usual practice of atomizing a liquid fuel, and we can dismiss the theory from present consideration.

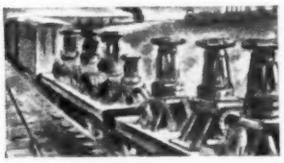
The next theory can be discarded with even less ceremony. Some have felt that the atomizing agent functioned somewhat as compressed air does in an air lift—by reducing the specific gravity of the oil. Lowering of specific gravity (density) naturally involves in-

View of oil heater furnace showing arrangement of tubes

The 1944 Outlook on STEEL VALVES

A frank statement of the problems facing steel valve users

If you have tried to buy steel valves during the past year you know that they have been among the most critical common components in American war production. Is there any relief in sight? How long will shipments take? Will repair parts be obtainable in 1944? *Here are the facts . . . .*

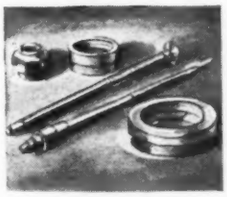


YOU CAN HELP SPEED DELIVERIES. Steel valve production has increased substantially in 1943, but in general has still lagged behind the extremely high demands of the war program. For at least the first part of 1944 this situation is likely to continue. There are, however, several things you can do to speed delivery of the steel valves you will need . . . .

1. Stick to standard valves. "Specials" slow down production, create order handling delays, and increase possibility that your order may not be filled since they usually require non-standard and short-run parts hard to obtain or manufacture.

2. See if a substitute is available. Often the exact type of valve you order may be oversold. In many cases a substitute valve type which will do the job as well will be available on a shorter delivery schedule.

3. Check your order. With steel valves, as with other critical war products, many delivery delays have had nothing to do with production. They have resulted from failure of the purchaser to furnish on the original order complete priority information, product description or service requirements.



WHAT ABOUT REPAIR PARTS? Requirements for maintenance and repair parts are naturally at a very high level as old equipment is stretched for long periods under extraordinarily heavy loads.

When a valve user orders a repair part he usually needs it in a hurry, and so we have given preferred treatment to repair part orders. Within the limitations of government regulations we will continue to emphasize prompt filling of repair part orders. Out of the great volume of part orders we filled in 1943, less than a handful were ever past due.

WHAT'S HAPPENED TO QUALITY? Today's Edward valves are just as good as they always have been. Recognizing that the service into which war valves go is often tougher than peace-time requirements, Edward has never relaxed material and workmanship standards. Actually there have been few changes in the materials used in Edward valves and in no case has inherent serviceability been reduced.

Nor have expanded operations and manpower losses to the armed forces altered the quality of Edward workmanship, for ours is a veteran organization with a large enough nucleus of thoroughly experienced valve builders to retain our rigid policy of every-stage inspection control with absolute power of rejections.

WHAT'S COOKING? Design development did not stop with the war. Edward engineering and laboratory departments have carried on an uninterrupted program of design refinement. Instead of withholding the results of this development program for a post-war splurge, each improved design—as soon as its value has been proved beyond question—was adopted as Edward standard practice in all cases where war production would not be jeopardized by such change.

Additional types of Edward valves will soon be available, probably before the end of the war. You can expect an announcement in the near future.

For as long as the war continues, the Edward plant will devote its facilities to the kind of on-schedule production that has won the Victory Fleet Flag, the Maritime "M" pennant, and an additional Gold Star, without prejudice to the service and planning needs of purely peace-time customers. And when V-day comes, the Edward plant will be ready.

W. F. Crawford
President

The Edward Valve & Mfg. Co., Inc.

Building a complete line of steel valves for all land and marine service temperature and pressure conditions.

EAST CHICAGO **INDIANA**

crease in volume, which cannot take place because of the pressure being held on the oil.

The most important way in which steam aids atomizing is by the mechanical blow caused by its sudden expansion from line pressure to virtually atmospheric pressure. The force of that blow is measured by the energy that was put into the water at 212°F. to bring it to the pressure used at the burner. There may be some help given by the two theoretical aids but the writer does not evaluate them highly. The importance of heat in reducing the viscosity, thus causing the oil to break up—atomize—into small particles, must be given proper weight. Needless to say, the smaller the particles are, the more intimate the mixture with primary air and the better the combustion. A word of caution in the matter of temperature of the oil is in order. If the viscosity is brought too low before reaching the burner, trouble from precipitated coke and sludge may be expected. The combating factor here is high velocity.

Nature of Atomizing Steam

Quality of steam used for atomizing has seldom been given much consideration, perhaps less than other features of the oil burning operation. Some have thought to justify the use of wet steam by the contention that the particles of water, in reevaporating at the burner tip, released energy that was effective in breaking up the oil. To some extent this is true, but the loss of B.t.u. by the reevaporation at least equaled the gain made by its disruptive effect.

The writer had an enlightening experience on the matter some 15 years ago. In rebuilding a small vapor phase cracking plant that had previously failed to function satisfactorily the construction of the heater's burner arrangement was changed so that four small burners were placed on each side alternating in position. Firing tunnels were provided for each burner with checker work arches. Fuel available was the plant bottoms, which was of consistency that caused the stock to be a solid at atmospheric temperature. The oil was heated by a coil in the base of the stack to about 450°F. Included in the process was the use of steam superheated to a point which, at that time, was almost without precedent, 1000 to 1200°F.

The steam line from the superheater to the process area passed the heater en route and it was decided to try using this extremely high temperature steam to atomize the heavy fuel. At the stated temperature the steam was a completely colorless gas. By the time the brickwork of the heater was at an even temperature and the unit was on steam it was found necessary to keep reducing flow of oil to burners almost to their low limit. The inside of the combustion chamber, including the firing tunnels, showed complete absence of color—pure daylight in fact. The operation was continued and a check showed very low fuel consumption for the amount of heat absorbed. In fact, the efficiency was too good to be accounted for purely on the basis of the steam quality and temperature. The theory of partial dissociation of the steam at the high temperature presented itself but we could not get any of the scientific authorities to say other than that which we all knew—that the dissociation temperature of the H_2O molecule was 3000°F. The writer was not satisfied with this and made further research in the matter, the result of which is a conviction that there is a partial dissociation of H_2O at 1000°F., which continues through to the temperature of complete dissociation and that the good results obtained by use of the extremely high temperature steam could be credited, in some degree, to the release of nascent hydrogen and oxygen by the partial dissociation.

In arriving at this conviction no thought exists of having repealed that law of science that states that energy is never lost or gained. The total always remains the same but, by changing its form sometimes a net gain may be had simply because of the greater availability of the energy to a specific process. The energy recovered in B.t.u. of hydrogen and oxygen is balanced by the energy consumed in the dissociation of the H_2O molecule.

Control of Fuel Oil

Not the least of the reasons that make a gaseous fuel preferred over oil is greater ease of control. In volume units, a B.t.u. of heavy liquid fuel takes up about one-thousandth of the space occupied by the same heat value in a lean gas. The accurate control, then, of a liquid fuel is a matter of greater precision than that of a gaseous fuel. Due to temperature changes the viscosity of a heavy liquid fuel is likely to vary over a wide range and affect severely the quantity issuing from the burner orifice at a given pressure. Coke and other suspended solids, tarry materials, etc., which tend to collect on burner surfaces, due to high temperature of both oil and steam, are sure to add to burner troubles. What can we do to minimize these difficulties?

Assume that a circulating oil temperature of 250°F. has been decided upon as satisfactory from the angle of viscosity reduction and that a velocity of 5 ft. per sec. will be necessary to prevent precipitation of solids, etc., in the feeder line. The velocity, obviously, is a function of the quantity flow. With varying demand, how are we going to maintain constant velocity? Simply calculate the feeder line size to this velocity for minimum flow conditions and return the end of line to suction of a displacement pump through a valve that will offer accurate restriction characteristics. The type of valve will depend upon service conditions. If automatic or remote control is desired, the multi-ported, balanced motor valve will, of course, be necessary. Automatic control can be made to operate as a function of temperature of oil leaving the heater, of tube wall or of combustion chamber, as desired.

The outstanding advantage of this plan lies in the ability to maintain high velocity, turbulence, and constant temperature in the fuel oil while, at the same time, pressure against the burner orifice is held at a relatively low point, which makes for better control as it eliminates eddy currents.

Preheated Air

Whereas the advantage of preheating the combustion air for gas fuel is almost entirely reflected in higher flame temperature, the advantages, when using liquid fuel, are much more than that. As the combustion efficiency, in the latter case, is affected very materially by the degree in which the fuel is broken up — atomized — it should be obvious that a hot, dry air is of substantial aid to the atomizing steam in accomplishing this end, as well as increasing the flame temperature. One can find in this another parallel to the internal-combustion engine. The writer speaks from experience when he states that the efficiency of the carburetted engine in an automobile would be considerably better if the atomizing air could be permitted to make use of some of the waste heat of the combustion cycle. It is not practicable to do this, however, because the power plant is mobile and cannot, therefore, tolerate the weight and bulk of the materials necessary to accommodate the greater areas involved in handling the increased volumes of air and air-fuel vapor caused by added temperature. In the conventional aspirated engine barometric pressure is the only source of power to overcome the friction of moving the air and vapor and, consequently, every means must be taken to hold to a minimum the head loss due to friction. As supercharging the engine does away with this limitation, so does preheated air under plus-atmospheric pressure increase efficiency of burning liquid fuel.

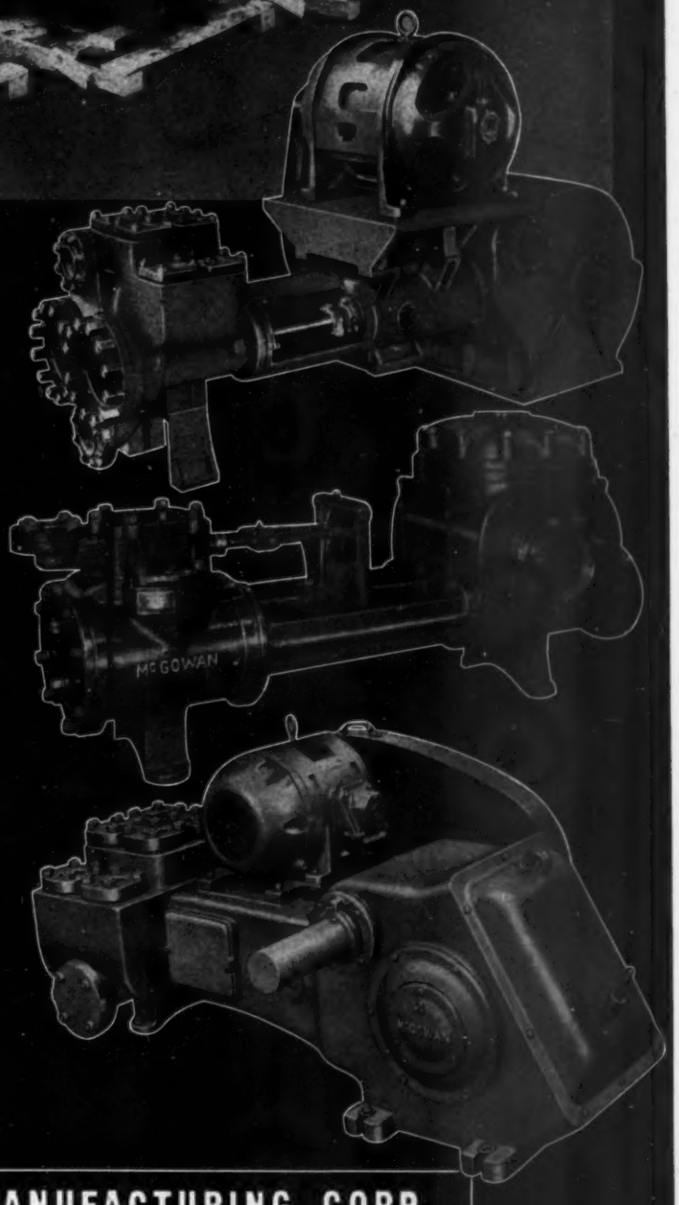
☆ ☆ ☆

Economist Prophesies

"Refinery petroleum output in 1944 will run 10 per cent above 1943. Higher prices for crude are probable."

—Roger W. Babson.

McGOWAN PUMPS *for the Petroleum Industry*



The McGowan Pump Division of the Leyman Manufacturing Corporation guarantees accurate workmanship and durable service. An experienced Engineering Department is available for information on installations and requirements. Highly efficient and ruggedly constructed — McGowan Pumps have the ability to stand up year in and year out under severe service conditions.

Dependable Since 1852

BRANCH OFFICES
Boston Norfolk
New York New Orleans
Philadelphia Portland
Houston San Francisco
Los Angeles Seattle
Chicago

For Complete Engineering Data — Write To:
McGOWAN PUMP DIV., LEYMAN MFG. CORP., Central Ave., Cincinnati 2, Ohio, U.S.A.

McGOWAN PUMPS

LEYMAN MANUFACTURING CORP.
The JOHN H. McGOWAN *Co.* DIVISION
59 CENTRAL AVE., CINCINNATI, OHIO

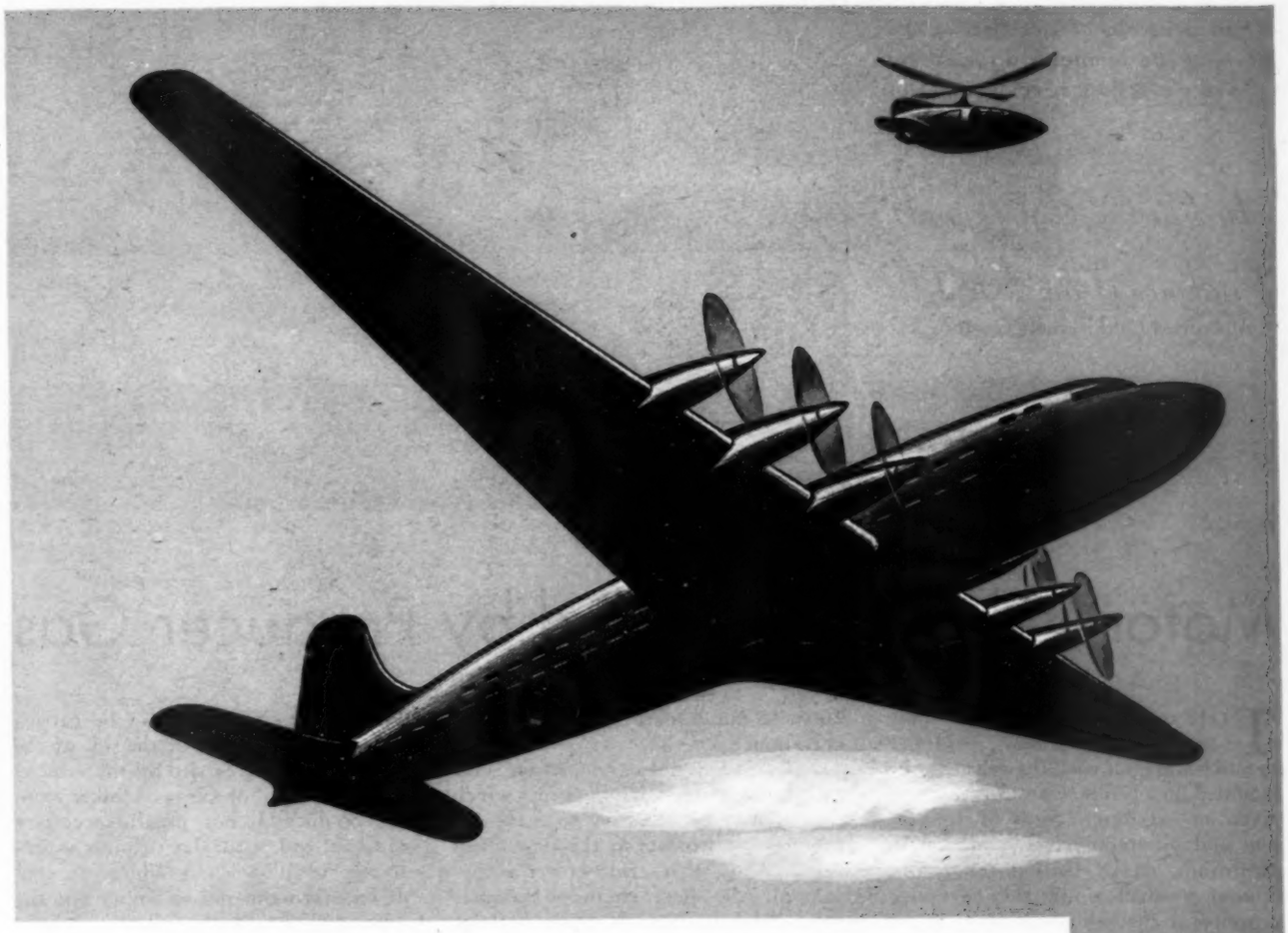
TODAY'S SIGNS FORECAST

It will be a changed world. Some may think that the nation's refinery and petro-chemical equipment for war will serve adequately for the needs of peace. But still greater accomplishments are possible. And the inevitable struggle for competitive post-war advantage will certainly develop them.

Good as war-built plants and equipment may be, it is not enough to rest on their pattern. Reconversion or refitting for peacetime requirements calls for study *now*.

Adding to the experience of a long pre-war career, Badger has learned much during the past three years of handling many construction projects — small, large and huge — for the manufacture of high octane gasoline, synthetic rubber stocks, explosives, and all sorts of chemicals new and old. This rich experience is available to you in change-over, modernization

PROCESS ENGINEERS AND CONSTRUCTORS FOR THE



TOMORROW'S NEEDS

or new-plant undertakings. Badger is equipped to handle *everything*—under sole responsibility or in co-operation with your own organization . . . from process, design and construction engineering, to material procurement, to labor employment and supervision, down to test-run operation. Badger is open for discussions now.

• Licensing Agents for the Houdry Catalytic Cracking Processes; All-purpose Fixed Bed Units; Adiabatic Fixed Bed Units; Thermofor Units.

Badger has designed and built more catalytic cracking units than any other organization in the world.

E. B. Badger & SONS CO.

BOSTON **Est. 1841**

NEW YORK • PHILADELPHIA • SAN FRANCISCO • LONDON

PETROLEUM, PETRO-CHEMICAL AND CHEMICAL INDUSTRIES

A gas generator tractor hauling lumber—at the lumber station of the Sverdlovsk Forest Exploitation Trust

by Gustav Egloff and Prudence Van Arsdell
Universal Oil Products Company

PART 2
(Concluded)

Motor Vehicles Propelled by Producer Gas

THE report[19] discusses at some length whether the producer should be integral with the vehicle or be mounted on a trailer. Consideration was given to maximum speed of conversion and minimum costs, and also to minimum use of skilled labor and minimum effect upon the carrying capacity of the vehicle. In general the use of trailers was favored because of the difficulty of fitting the producer plant to vehicles not designed for carrying such plants, because of the reduction of fire risk in garages and the ease of substituting alternate producer gas units during servicing of others.

Mounting the equipment directly on the vehicle results in the least increase in weight and overall length, does not interfere with maneuvering or reversing, and makes easier the cooling of the producer gas prior to filtration. However, considerable difficulties are encountered when installing producer gas plants on diverse body types not originally designed for this purpose.

Operation

When the engine is cold, it is customary to start operations with gasoline and to use it as an exhauster to draw the flame through the fuel bed from a torch inserted into the mouth of the tuyere. Ignition of the fuel takes place in about one minute, and the complete starting operation, from the time of inserting the torch to the time when the vehicle moves off on producer gas, takes from two to four minutes.[19] The Russian[20] report states that from 10 to 12 minutes are necessary for this operation.

Full power is not developed for some 20 minutes after starting, during which time it may be necessary to make occasional adjustments in the air control valve. After that, full power is developed, the performance becomes steady, and the controls require little, if any, more attention than on a gasoline driven vehicle.

As the fuel is consumed, its level falls in the hopper and it becomes necessary to refuel the producer after a period, depending upon the size of the vehicle and the nature of the service. The fuel consumption of a vehicle with a gross laden weight of about 6 tons is normally from 1½ to 2 lb. a mile. In such cases some 120-150 miles may be covered on a single charge of anthracite, although this distance will be less with more bulky fuels, such as low temperature coke. Recharging the producer is a simple operation and can be carried out in a few minutes at the side of the road from sacks carried on the vehicle.

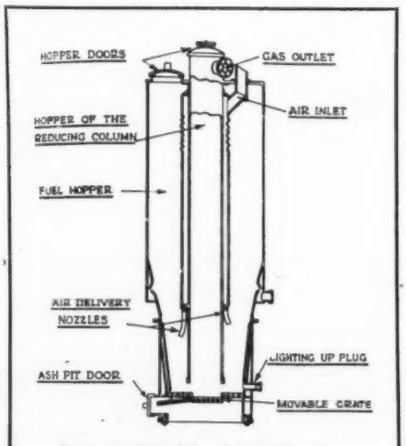


Fig. 6. Double-draught type

The removal of ash and clinker from the producer is not usually necessary until the end of the day's run. It is preferable to allow the producer to cool down overnight and to empty out the ash and clinker on the following morning. It is advisable to empty the producer and to recharge it with fuel after each day's run, even though a long distance has not been covered, as it is difficult to get rapid ignition with partly consumed fuel.

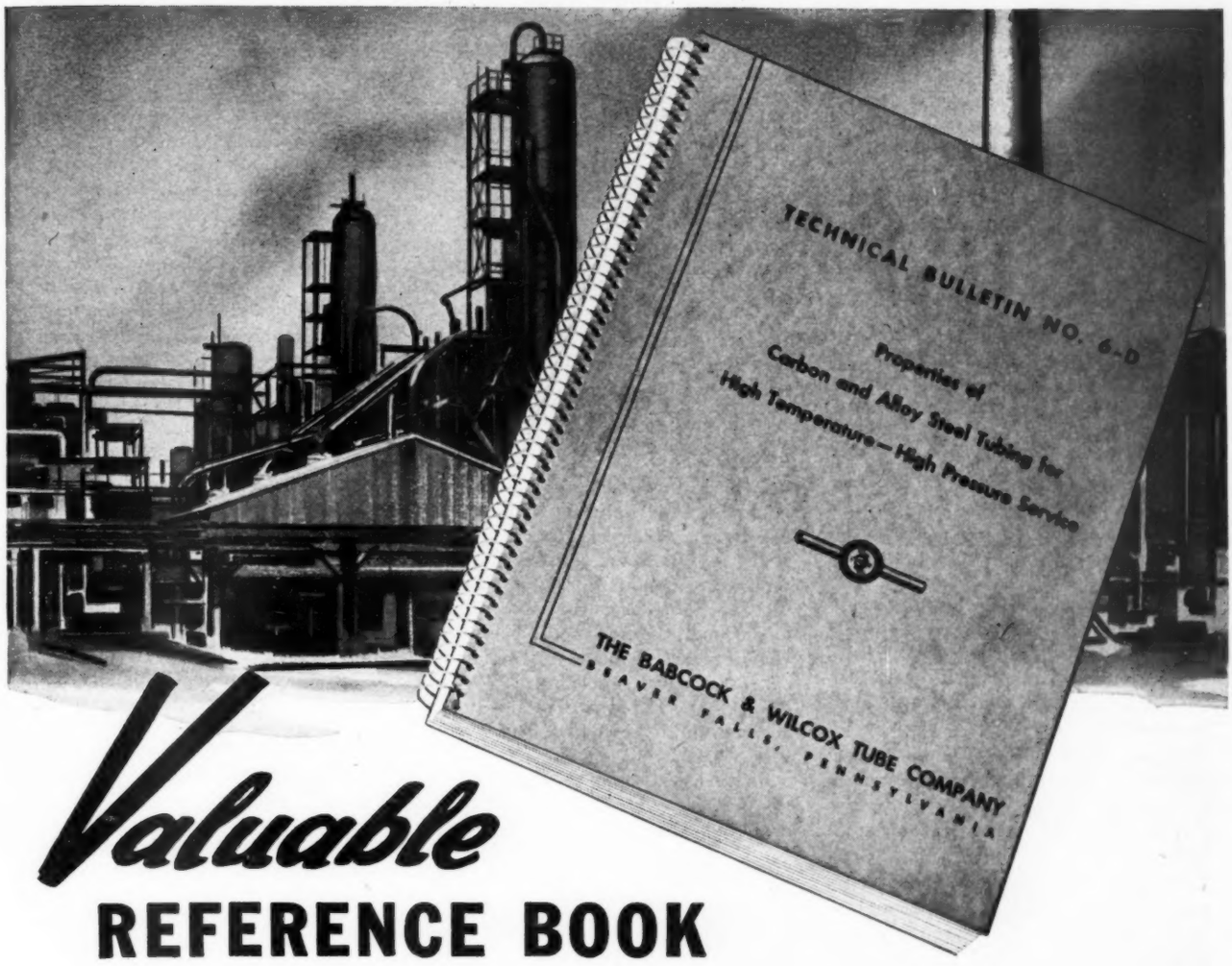
When the producer has been emptied, it is desirable, for the sake of economy after removing lumps of clinker, to screen the fuel discharged and to mix all the partly consumed fuel above $\frac{3}{16}$ in. in diam. with fresh fuel to be used on refueling the producer; but, naturally, better results can be obtained with fresh fuel than with partly consumed fuel.

For a good start after a short halt of up to about a quarter of an hour's duration, it is desirable to keep the engine idling while the vehicle is stopped, in order to maintain the fuel bed in good condition. If required, a start can be made after idling for periods up to about one hour or more, but if the engine is stopped for a period of this length, it will usually be necessary to start it on gasoline and to "draw up" the fire before changing over to producer gas. It should not be necessary to apply a torch to the tuyere as in starting from cold.

The most likely cause of cylinder wear with producer gas is abrasion arising from bad filtration due to errors or carelessness in the fitting or in the

[19]Report of the Committee on the Emergency Conversion of Motor Vehicles to Producer Gas, Great Britain (1939).

[20]I. A. Zasov, Automobile—U. S. S. R. Auto Manual, Chap. IX, pp. 207-241, Moscow, 1942.


TECHNICAL BULLETIN NO. 6-D
Properties of
Carbon and Alloy Steel Tubing for
High Temperature—High Pressure Service
THE BABCOCK & WILCOX TUBE COMPANY
BEAVER FALLS, PENNSYLVANIA

Valuable REFERENCE BOOK

FOR REFINERY ENGINEERS

Almost every day refinery engineers and chemists have use for a reference book thoroughly covering the subject of steel and alloy tubing for the petroleum industry. Such a book—Technical Bulletin 6-D—prepared by Babcock & Wilcox, is available free.

Technical Bulletin 6-D, prepared after much intensive research and study of Refinery Problems, contains 157 pages of technical data, much of which has never before been published. It covers such subject matter as: Manufacture of B&W Seamless Croloy Tubes; Facilities for Research and Testing; Influence of Alloy Elements; Chemical Composition; Rupture and Creep Testing; Thermal Expansion data; Microstructure; Air-hardening Properties.

Babcock & Wilcox will be glad to send you a copy of this Bulletin. Just write request on your business letterhead.

TA-1261

★ BACK THE ATTACK— BUY MORE WAR BONDS! ★

THE BABCOCK & WILCOX TUBE CO.

•

SEAMLESS DIVISION **BEAVER FALLS, PA.**

maintenance of the filters. It is most important that the filters be given regular attention, the nature of which will depend upon which of the alternative types of filter is employed. If this is done, cylinder wear should not be excessive.

Many of the present-day installations in Great Britain have the cross-draught type of gas generator.

Double-Draught, Double-Zone

Double-draught producers work on the principle of the upper part of a bed of fuel burning downward and causing volatile matter to be driven off so that the volatile matter then passes through the upper incandescent zone of the lower up-draught part of the fuel bed to cause complete decomposition. In double-zone producers two fuel beds may be employed; these are arranged one within the other, and separate fuel feeds are provided for each bed. The air supply may be downward only through the outer bed, so that the hot gases then pass upward through the inner fuel zone. Alternatively, two air feeds may be employed.

Fig. 6 shows a type of double-zone producer manufactured and operated in France. As to the operation of this producer the following statement is quoted:[18]

"This interesting double-zone generator is designed to use wood, though a certain quantity of charcoal is also consumed simultaneously. The cylindrical producer shell has within it a second cylinder of approximately one quarter of the outside diameter. The inner cylinder contains charcoal, and between the two is wood. Immediately without the circumference of the inner cylinder is an annular space through which air is drawn from the top of the generator, and is delivered to the first fire zone by vertical tuyeres.

"The air passes downwards through the wood toward the grate, the fire zone being insulated against heat loss both by a refractory liner and an air gap. The inner cylinder descends about four-fifths of the vertical distance between the tuyeres and the grate. Under its lower rim the gases pass, and then rise through the charcoal reducing column. A pure and clean gas is said to result from this construction.

"The grate has a rotatable center section, access to which (as to the ashpan) is obtained through a door on the circumference of the base.

"A further novel feature of this design is the method of drawing off excess moisture, etc., during periods of light load. Tubing connects the outside envelope of the producer to the engine's exhaust pipe, the gas being led through a condenser. The passage of gas through this system is regulated by an automatic valve, the opening of which is made to depend upon the degree of suction or otherwise in the engine's inlet manifold. Moreover, a set screw in the valve itself regulates the degree of its opening, the setting being more open for resinous than for other woods."

In double-draught producers the air flow may be arranged in two separate feeds both currentwise, with one upward.

Points of importance in regard to the design of double-draught producers are:

(1) The fire areas and depths.

(2) The relationship of the fire zones to each other.

(3) The positions of air entry and the method of distribution.

(4) The position of the gas exit and its relation to the air feeds.

The greater part of a gas producer is made of sheet metal.[21] Hoppers, coolers, and filters are usually galvanized or painted to lessen corrosion. Grates and tuyeres are made of alloys to resist heat, high temperatures, and oxidation. The generator is lined with a refractory such as carborundum, magnesite, bauxite, or fire clay. On trucks the generator is commonly mounted near the front and may be placed at either side or just back of the cab. On busses and pleasure cars it is in the rear and may be carried on a small two-wheel trailer. Coolers are ordinarily placed beneath the vehicle. The filter is also placed there, provided it is horizontal; if vertical, it is located somewhere else. A final filter, if used, is located near the intake manifold.

American-Made Gasogenes

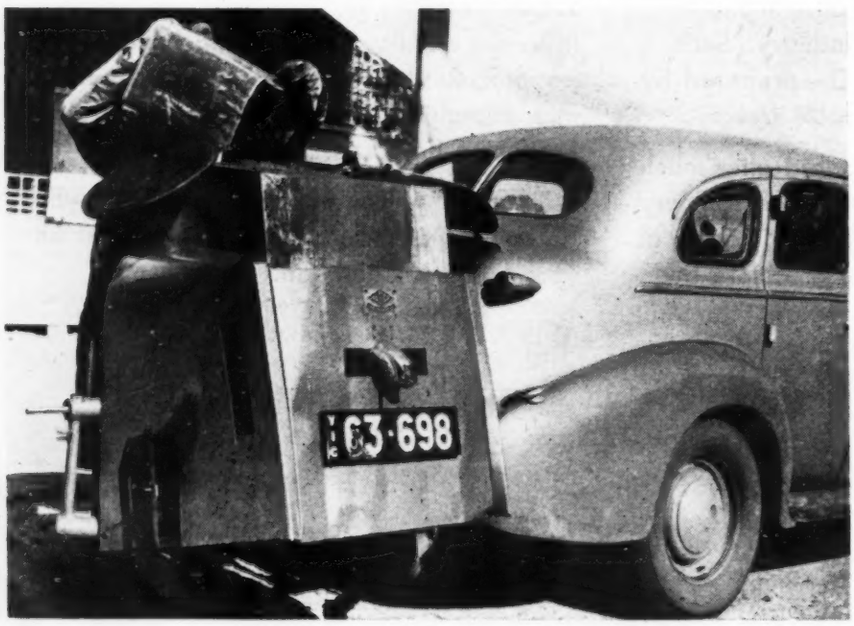
Producer gas generator sets designed for charcoal fuel are being manufactured in the United States for China under lend lease terms. They are not available for civilian use in this country.[22, 23, 24, 25]

A unit of equipment weighs 375 lb. and consists of a generator, a series of four filters, a small tank to feed water and enrich the gas, a 3 in. gas tube encircling the chassis, and an 11 in. diam. short cylinder that serves as a carburetor. The gases are drawn in from the generator line and forced into the carburetor by a fan driven by a belt on the engine crankshaft. For passenger cars the generator is carried on a single wheel trailer or installed in the rear trunk space. On trucks the equipment is supported either on a fender or behind the cab. There is a dual control arrangement to permit the use of either gasoline or producer gas.

In operation the generator is charged with charcoal of from ⅜ to 1 in. diam. No diagrams are given, but apparently the charcoal falls from a hopper into a lower firebox. It is stated that from one to two minutes are required for gas to build up and that the generator will hold enough gases for starting after parking one hour in ordinary weather. A 50-50 mixture of producer gas and air passes through the carburetor. Speeds of 30 to 35 miles per hour are attained. After 60-100 miles of driving, wood ashes are withdrawn, and the

[18] B. Goldman and N. Clarke Jones, *J. Inst. Fuel, 12*, 103-140 (1939)

Australian automobile gas producers



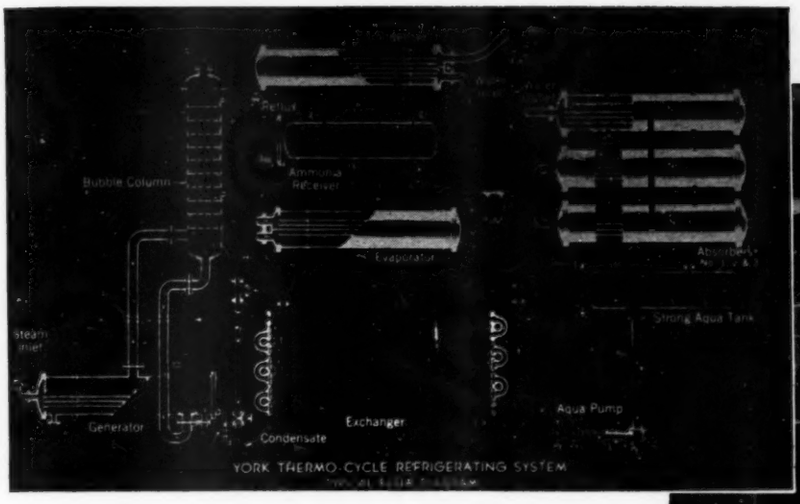
[21] C. H. Vivian, *Compressed Air Magazine*, September, 1942.

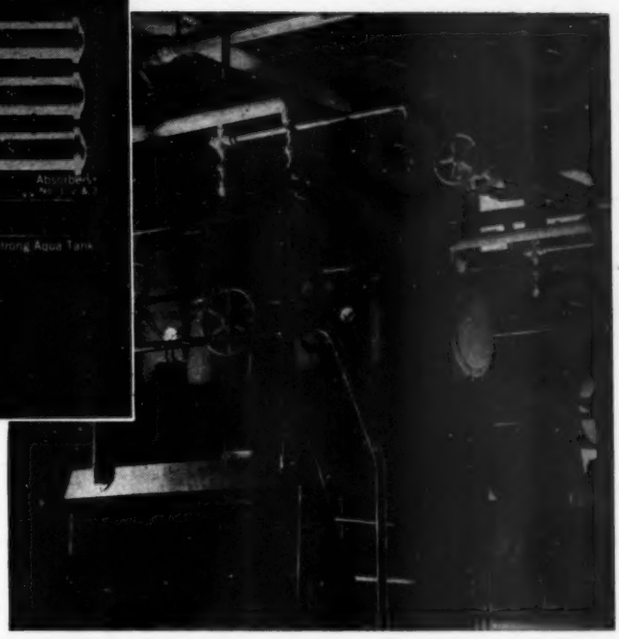
[22] "Woman Who Fled Nazis Makes Gas Producers in Michigan Plant for Export to China," *National Petroleum News*, p. 17, October 20, 1943.

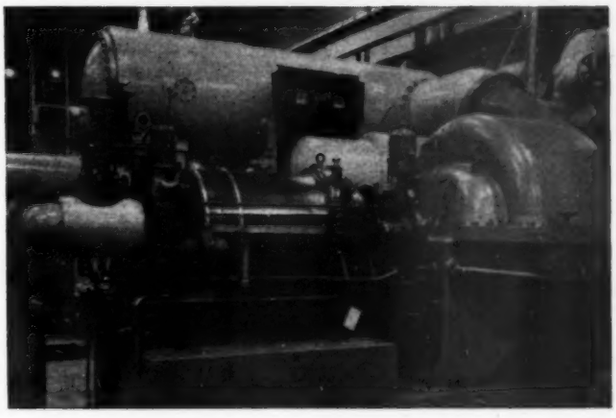
[23] "Charcoal Made for Car Fuel at Tribune Farm," *Chicago Tribune*, August 2, 1943.

[24] "Tribune Farm Charcoal Fuels Truck on Tour," *Chicago Tribune*, August 3, 1943.

[25] "Charcoal Gas Propels Truck on 180 Mile Run," *Chicago Tribune*, August 4, 1943.







It's got to be right... the **FIRST** *time!*

THERE's more than one way to get industrial cooling, but there's only one *best* way in each situation.

Whether you use the Thermo-Cycle absorption system, a reciprocating compressor or a turbo compressor, the York name plate means it's the right equipment in the right place.

For, back of the traditional soundness and dependability of York machines is the competence and integrity of York application engineers. They can be of immense help in these days when time is so precious and errors come close to treason. Backed up by a manufacturing policy and facilities that provide them with every type of mechanical cooling, these men can help you do the job right . . . the first time. York Corporation, York, Pennsylvania.

ARMY (E) NAVY

YORK REFRIGERATION AND AIR CONDITIONING FOR WAR

HEADQUARTERS FOR MECHANICAL COOLING SINCE 1885

generator is recharged with charcoal.

A number of test runs have been made as follows:

1. A 1½ ton Chevrolet truck was driven for 100 miles on the Indianapolis Speedway at an average speed of 35 miles per hour; 125 lb. of wood charcoal was consumed in the run, or 1.25 lb. per mile.

2. A 2½ ton vehicle was driven from Wheaton, Illinois, to Kalamazoo, Michigan, a distance of 180 miles at an average speed of 30 miles per hour; 175 lb. of wood char were charged at the beginning of the run, but it is not stated whether this was sufficient to complete the distance.

3. A 1½ ton Chevrolet truck was tested at Iowa State College and found to require 1.38 lb. of wood charcoal per mile. The truck was driven 168.6 miles on 233.21 lb. of charcoal.

4. A 30,000 mile trip was begun in August, 1943, which is not yet completed. A 1942 Roadmaster Buick and a 1½ ton Chevrolet truck are to be driven for three months in all kinds of weather, partly on gasoline and partly on charcoal.

Thus far charcoal has been the only fuel used but tests are to be made using anthracite coal and coke. The makers of the equipment state that 12 lb. of charcoal are equivalent to 1 gal. of gasoline. Charcoal now costs $40 a ton. In the Iowa State College test the cost was $2.75 for 168 miles of travel, or 1.64 cents per mile.

Reactions in Manufacture

As has been shown, solid fuels are extremely varied substances, and their conversion into gas is a complex reaction; however, the thermochemical changes can be shown in the following briefly summarized equations:[18]

$$CO_2 + C \rightarrow 2\ CO - 38{,}800\ \text{Cals.} \quad (a)$$
$$2\ C + O_2 \rightarrow 2\ CO + 58{,}800\ \text{Cals.} \quad (b)$$
$$C + O_2 \rightarrow CO_2 + 97{,}650\ \text{Cals.} \quad (c)$$
$$2\ CO + O_2 \rightarrow 2\ CO_2 + 136{,}400\ \text{Cals.} \quad (d)$$

When water is used, or when there is considerable moisture from the fuel drawn into the fire bed:

$$H_2O + C \rightarrow CO + H_2 - 28{,}800\ \text{Cals.} \quad (e)$$
$$H_2O + CO \rightarrow H_2 + CO_2 + 9{,}400\ \text{Cals.} \quad (f)$$
$$C + 2H_2O \rightarrow CO_2 + 2H_2 - 18{,}800\ \text{Cals.} \quad (g)$$

Some types of gas generators now marketed are making use of the higher calorific power obtainable from gas that has had water added during combustion of the fuel, because by the use of water in fuel beds attaining a high enough temperature, a water-gas mixture rather than carbon monoxide alone is the product. Upon long idling of an engine, however, the temperature of the fuel may decrease sufficiently to prevent the decomposition of water on contact, so that it will pass through as steam, be condensed in the cooling and cleaning coils of the producer, and give rise to difficulty in operation.

In Germany wood is recommended as the fuel for producer gas plants on motor vehicles.[26] Some of the advantages of wood are quoted as follows: (1) Low ash; (2) freedom from sulphur; (3) uniformity in chemical composition; (4) ease of ignition, and (5) formation of structurally strong carbon. The average composition of dry wood is given in Table 3.

TABLE 3
Chemical composition of wood

	Approx. per cent
Carbon	50.0
Hydrogen	6.0
Oxygen	43.0
Nitrogen	0.1
Ashes	0.9

The water content of the wood should be from 10 to 25 per cent.

The reference states that peat is also very well adapted for producer gas generators, although the ash in peat is generally higher than in wood and the sulphur content may be a disadvantage. The moisture content should not be more than 25 per cent and not under 20 per cent. The ranges of composition are given for peat in Table 4.

TABLE 4
Chemical composition of peat

	Per cent
Carbon	50.2 -60.2
Hydrogen	4.45- 5.8
Oxygen	30.6 -39.4
Sulphur	0.2 - 4.0
Nitrogen	0.9 - 3.0
Ash	1.9 -20.0

The producer gases[27] derived from wood and charcoal have an approximate composition as shown in Table 5.

Wood and charcoal have been the most commonly used fuels for producer gas vehicles. The Russians, recognizing this fact, have given a number of generalizations on the utilization of wood in generator vehicles:[20]

1. Water content of wood should range from 15 to 20 per cent absolute.

2. Wood should not be rotten or contain foreign matter. All kinds of wood are suitable for the producer gas vehicle, although preference is given to the leafy species, such as birch, oak, and ash, because of their higher heat content on the basis of volume charge and their greater strength of resulting charcoal.

Freshly cut wood contains from 40 to 60 per cent water. When such wood is used, considerable power is lost in generation of steam and low heating value of the wood.

3. The apparent densities of different kinds of wood chips, expressed in lb. per cu. ft. based on a moisture content of from 15 to 20 per cent, are given in Table 6.

TABLE 6
Apparent densities of wood chips

	Lb. per cu. ft.
Oak	20.0
Birch	20.0
Pine	17.4
Fir	16.6

In the operation of the producer gas vehicle the temperature varies with the zones set up in the gas generating equipment.[20] These various zones are marked in the furnace or tuyere as shown in Table 7.

TABLE 7

	Temperature ranges, °C.
Drying zone	Up to 200
Distillation zone	Up to 600
Reduction zone	Up to 1100
Burning zone	Up to 1300

As the temperature increases above 200°C., a solid fuel begins to break down. The products of dry distillation up to 600°C. are rosin, acetic acid, wood alcohol, and small quantities of CO and CO_2. In the 1100°C. zone CO_2 is reduced to CO, which is the major constituent of producer gas and the source of mechanical energy when oxidized in the cylinders. When steam enters the reduction zone, some of the hydrogen produced combines with the carbon to form methane, and the oxygen combines to form carbon monoxide. The major portion of the hydrogen does not combine, but remains as free hydrogen. Large percentages of methane and free hydrogen contribute considerably to the power output of the engines.

Table 8 shows the calorific values of gasoline and a number of the fuels used in producer gas generators.

[26] *Oel Kohle*, September 22, 1942.

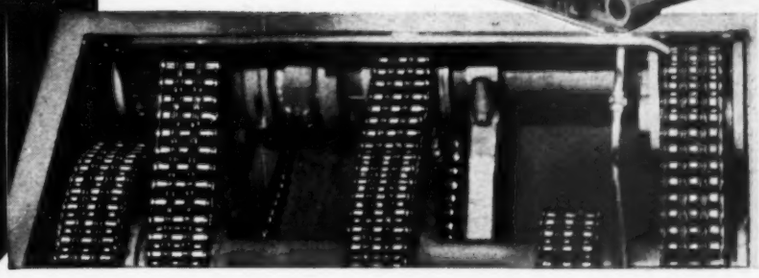
[27] H. A. Branders, *Automotive Ind.*, May 1, 1942.

TABLE 5
Producer gases

	Wood (Average per cent)	*Russian data*	Charcoal (Average per cent)	*Russian data*
Carbon monoxide	20	20	30	28
Carbon dioxide	11	8	2	5
Hydrogen	17	12	10	3
Hydrocarbons	2	2	0–2	2
Nitrogen	50	58	56–58	62

Unit Rig 3-engine Model U-10 with 6-speed Diamond Roller Chain Transmission.

ON EQUIPMENT SO VITAL TO OIL PRODUCTION

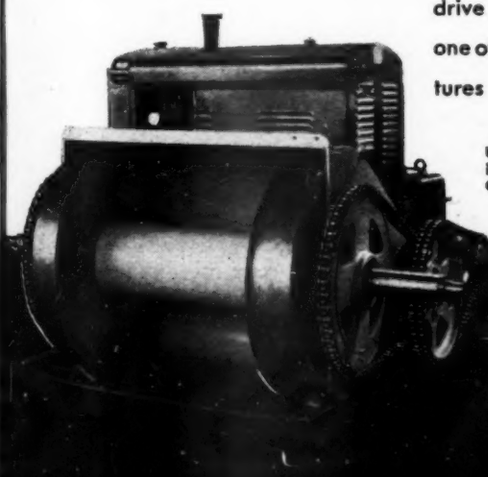


Above: View showing portion of the compact transmission assembly of Model U-10 rig, the design of which incorporates triple-strand Diamond Roller Chains.

Moterig, self-propelled by the drilling engines from the Diamond Chain driven compound. This rig is for slim hole drilling.

● With petroleum the life blood of mechanized warfare and essential civilian transportation—unfailing performance of oil field drilling equipment is more vital than ever. This equipment must stand up under long hours of continuous operation,—must make hole faster,—and must always be fit and ready for the next job.

The power drives thus are of great importance, and Unit Rig, like all leading makers of drilling equipment, for years has used Diamond Roller Chain Drives. The compact 6-speed Diamond Roller Chain transmission that provides six speeds for the rotary drive and for the drum is one of the outstanding features of the Model U-10.



Unit Rig Model U-24 service hoist with Diamond Chain Drives from engine.

Since the early days of modern types of oil country drilling rigs,—drillers, tool pushers, contractors, and the engineers of the machinery manufacturers have recognized the outstanding advantages of DIAMOND Roller Chain Drives,—their long life,—smooth operation, and their reserve capacity to withstand the severe shocks and loads of drilling and handling heavy strings. They know too that with these drives the load is distributed over many sprocket teeth, separating forces are eliminated, bearing loads reduced,—maintenance on the job cut to a minimum . . . DIAMOND CHAIN & MFG. CO., 441 Kentucky Ave., Indianapolis 7, Ind. Tulsa Office: 2238 Terwilliger Blvd.

TABLE 8

Fuel	B.T.U.'s per lb. (approx.)
Gasoline (60 A.P.I. gravity)	20,250
Anthracite	14,800
Low-temperature coke (externally heated retort)	14,200
Charcoal[18]	13,428
High temperature coke (activated)	13,420
Low temperature coke (internally heated retort)	13,224
High temperature coke (unactivated)	13,200
Peat[18] (charcoal briquet)	12,800
Brown coal (char)[18]	12,040

The average weight of solid fuels used for producer gas manufacture is more than twice that of gasoline. The values are shown in Table 9.

TABLE 9
(One gallon of gasoline, 6.2 lb., equivalent to pounds of solid fuel)

	Lb.
Wood	20.0
Wheat	20.0
Anthracite	15.0
Charcoal	12.5
Coal	12.0

It is interesting to note in Table 10 the weight of equipment in producer gas propelled vehicles using different solid fuels. The increased weights of the motor vehicles range from 360 to more than 1000 lb.; these may be contrasted to the weights of the vehicles when gasoline is used instead of solid fuel.

Compression Ratios

The compression ratios on the producer gas vehicles vary from about 4.7:1 for the converted automobile engine without special cylinder heads, to about 14:1 for those fitted to handle the gas. Ratios as high as 16.2 have been tried with fairly successful results; but for engines that must be changed over from gasoline to producer gas when starting, the ratios from 6.5:1 to 9:1 are more satisfactory, and even the 9:1 is on the high side. For those engines having higher than 10:1 ratios, special cylinder heads are necessary; and for the 14:1 to 16.2:1 ratios, the design of the piston and cylinder head is of especial importance. As the ratios increase, the efficiency as compared to that of gasoline also increases. For the engines using producer gas without any change in the engine, the efficiency of the producer gas as compared to that of gasoline is about 50 per cent. For the highest compression ratio, 16.2:1, the efficiency as compared to that of gasoline is between 75 and 80 per cent.

Poison Hazards

From the experience of Sweden, which operates a large number of producer gas driven vehicles, there is a definite hazard to drivers from exposure to the generated gases.[28]

"Cases of poisoning through inhalation of producer gas are becoming so numerous in Sweden as to engage the closest attention of the authorities. A special hospital department has been established at Stockholm to deal exclusively with such cases, and a film showing the various kinds of danger to which persons dealing with producer gas plants are exposed has been produced. Producer gas poisoning is now recognized as a typical professional disease to which motorists are liable.

"According to recent Swedish statistics there occurred only 60 cases of producer gas poisoning in Sweden in 1940 (seven fatal), but in 1941 this rose to no less than 901 cases (17 fatal), while in 1942 the number was 1,135 (11 fatal).

"Periodic examination of drivers and workpeople dealing with producer gas plants confirmed that the greatest danger is not embodied in acute cases of poisoning but in chronic poisoning through habitual inhalation of gas reflecting in a very deleterious way on the general state of health of the person concerned. Chronic poisoning, i.e., not acute cases, is said to be much more widespread. As against only three such cases in 1940, 1144 and 2578 were recorded in 1941 and 1942, respectively, but it is believed that these latter two figures represent only about one-third of the total number of cases of chronic producer gas poisoning in Sweden. It is stated that habitual inhalation of such minute proportions of the gas as 0.01 per cent results eventually in a dangerous deterioration in health. The general fitting of gas indicators to producer gas plants is urged."

[28] *Petroleum Times*, September 4, 1943.

TABLE 10

Name of producer gas equipment	Classification of equipment	Country in which used	Weight (lb.)	Fuels used	Compression ratio
Malbay	Up-draught	France	840	Charcoal, low-temp. coke, anthracite	7.45
Wisco	Up-draught	Germany	1000 65 hp. water and fuel	Charcoal, low-temp. coke, peat coke, anthracite	6.80
Humbolt-Dentz	Up-draught	Germany	1800 90 hp. inc. water and fuel	Tar-free fuels, anthracite, low-temp. coke, charcoal	.....
Gohin-Poulenc	Cross-draught	France	360	Charcoal low-temp. coke, anthracite, mixed anthracite and charcoal	High compression heads fitted
Brandt	Double-zone	France	1000-1100	Mixed wood and charcoal	.....
Koela	Up- and down-draught	Great Britain	375-425 65 hp.	Charcoal, low-temp. coke, peat briquet, anthracite	6.50-7.50
Gaz-42	Down-draught	Russia	794	Wood chunks	.....
Zis-21	Down-draught	Russia	1202.5	Wood chunks	.....

Conclusions

Many countries faced with a gasoline shortage due to the war are resorting to increased use of producer gas as motor fuel. The greatest use is shown in Germany and in Axis-dominated European countries. From 9000 producer gas vehicles in operation prior to the war, the number has increased in four years to more than 820,000. It has been estimated that these producer gas vehicles have substituted for about 25,000,000 bbl. of gasoline in 1942. In countries most advanced in the development of gasogene vehicles, the present trends are in the direction of standardizing on limited designs adapted to use standard types of fuels, particularly wood and coal. Each type of solid combustible has to be handled differently. The types of gasogenes include up-draught, down-draught, cross-draught, and double-draught models. Producer gas plants have been installed on automotive vehicles of all types, on motor driven boats, and on stationary engines. Gasogene vehicles are characterized by slow starting, poor maneuverability, low power output, and operating difficulties in the hands of inexperienced drivers who have been accustomed to gasoline powered motors. To operate a gasogene vehicle requires a mechanical sense and far greater care than that needed to run a gasoline-propelled vehicle. Experience in Sweden has shown that there are definite hazards to be considered from exposure to the producer plant gases, which contain high percentages of carbon monoxide. From an economic standpoint the gasogene vehicle is best adapted to long hauls at moderate and uniform speeds. —— ☆ ☆ ☆ ——

PIONEER SERVICE DEDICATED TO THE ADVANCEMENT OF THE OIL INDUSTRY

Eighteen years ago, National Lead Company introduced BAROID to the oil industry. AQUAGEL was next developed, and then followed many other Baroid Products which have made valuable contributions to safer, faster, more economical drilling.

Unequalled laboratory service at Houston, Los Angeles, and Tulsa supplements the use of Baroid Products. Baroid technicians, in addition to maintaining and improving the quality of Baroid Sales Division's well-established products, are constantly at work developing new materials, new applications and new processes for the prevention of drilling troubles through mud control.

Baroid Service Engineers, in laboratory-equipped cars, cover the oil fields and provide a day-and-night service. This service, in collaboration with oil company mud engineers, has resulted in large savings for the oil industry by reducing drilling difficulties; by saving casing; and, in many cases, by the actual saving of wells.

BAROID, and other Baroid Products, are immediately available in more than 400 locations in the United States and Canada.

Patent Licenses, unrestricted as to sources of supply of materials, but on royalty bases, will be granted to responsible oil companies and operators to practice the inventions of any and/or all of United States Patents Nos. 1,807,082; 1,991,637; 2,041,086; 2,044,758; 2,064,936; 2,094,316; 2,119,829; 2,214,366; 2,294,877; 2,304,256 and further improvements thereof. Applications for Licenses should be made to Los Angeles office.

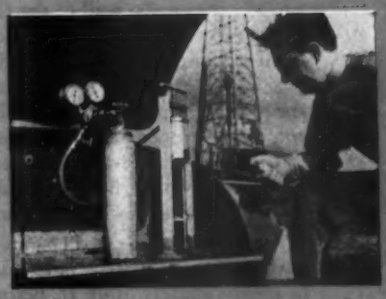
BAROID SALES DIVISION

NATIONAL LEAD COMPANY

Baroid Sales Offices: Los Angeles 12 • Tulsa 3 • Houston 2

In this small laboratory at the Los Angeles plant, Baroid Sales Division pioneered in preventing drilling troubles.

Baroid Sales Division maintains modern laboratories at Los Angeles, Tulsa and Houston.



Baroid Service Engineer testing mud at well with Baroid Wall-Building Tester.

Baroid Products: Baroid and Colox • Aquagel • Fibrotex • Baroco • Stabilite • Aquagel-Cement • Smentox Impermex • Zeogel • Micatex • Anhydrox • Testing Equipment • Baroid Well Logging Service

Cementing Casing Through Troublesome Zones

☆ **Discussion of method employed in well in which circulation was being lost and gas zones were present**

by Wallace A. Sawdon

Pacific Coast and Foreign Editor

TROUBLESOME zones frequently present such a hazard to further drilling that casing must be set and cemented before the well can be drilled to completion. Even the cementing of casing through zones where circulation is being lost is sometimes a problem because the best drilling mud, no matter how well prepared and conditioned, is usually unable to prevent loss of fluids into the formation while drilling under these conditions and thus cannot build a mud cake on the wall of the thief zone to prevent loss of slurry while the cement is being forced up behind the casing. When gas zones are encountered in the troublesome area, the problem becomes even more difficult. This was the case in a well recently drilled in the Ventura Avenue field, California, in which gel cement was employed.

After cementing a 11¾ in. surface string at 1501 ft., the hole was drilled to approximately 5000 ft. before it was decided that the loss-of-circulation and gas zones would have to be cemented off with casing set at 4400 ft. In order to use 9⅝ in. casing the hole was underreamed as shown in Fig. 1, the deeper underreaming being done with great difficulty. A cement bridge was placed at 4400 ft. and the 9⅝ in. casing string run, the upper 2000 ft. being made up of coupled joints with collars turned down to 10½ in. and the remainder consisting of flush joint pipe.

During the running of the casing mud returns were obtained until about 20 min. before the string was landed; after landing, fluid was pumped away for 20 min. without returns. Circulation thus being lost, the original plan of circulating with a low viscosity mud for an hour before cementing had to be abandoned.

Having decided to use a gel cement for cementing the casing, laboratory tests were made to determine the consistencies and angles of repose of slurries made by mixing 3 per cent prepared bentonite with slow set cement of 1400 surface area.[1] Based on these tests, shown graphically in Figs. 2 and 3, it was planned to use the 3 per cent gel cement for the entire 1000 sacks comprising the job and to mix all but the last 100 sacks with a water-cement ratio of 8 to 8.5 gal. of water per sack of cement, which would give a slurry weighing from 103 to 104 lb. per cu. ft. (13.6 to 13.9 lb. per gal.). The last 100 sacks were to be mixed with 7 gal. of water per sack to increase the weight to 107.6 lb. per cu. ft. (14.4 lb. per gal.) and give a harder cement with tighter bond around the shoe. The low weight slurry was employed to aid the gel cement in preventing dissipation into the formations taking fluid so easily by keeping the hydrostatic pressure as low as possible.

[1]The "surface area" as now used by manufacturers of cement as a specification of fineness is the sum of areas in square centimeters of the particles contained in one gram of the cement.

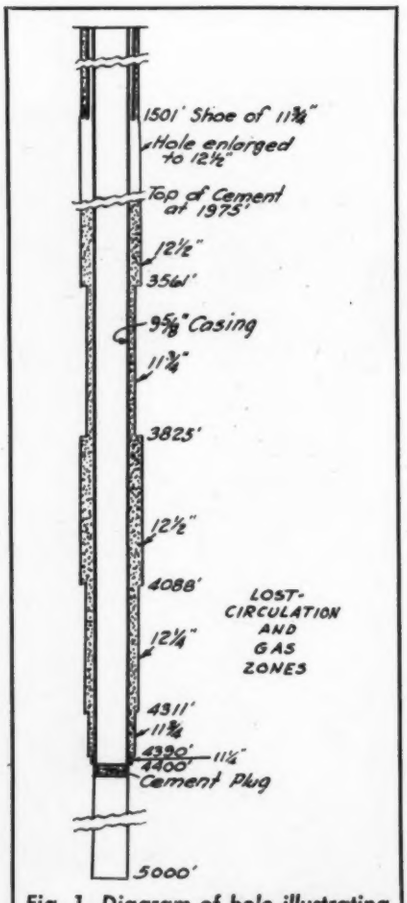


Fig. 1. Diagram of hole illustrating cementing operation

With circulation having been lost, however, it was decided to change the previously planned procedure and to use at first a gel cement having a higher angle of repose in order to shut off the thief sand and allow the slurry to rise to the desired height behind the casing. The cement was premixed with the 3 per cent of prepared bentonite and the higher angle of repose was obtained by making a 118 lb. per cu. ft. (15.8 lb. per gal.) slurry, which was mixed and pumped in for 5 min. This amount was considered sufficient to plug off the lost circulation zone and the originally planned mixture was then started through the pumps.

The 102 lb. per cu. ft. (13.6 lb. per gal.) slurry was mixed and pumped in for 25 min.; then, as there was no increase in pump pressure, the weight was increased to 107 lb. per cu. ft. (14.3 lb. per gal.) and this weight was maintained for 20 min. The weight of the remainder of the cement was then further increased to 109 lb. per cu. ft. (14.6 lb. per gal.) to give greater weight to the cement around the shoe.

The total mixing time was 65 min. and the displacement time 40 min. The cement was displaced with mud fluid and 25 min. after mud pumping was started the pressure increased from 60 lb. per sq. in. to 550 lb. per sq. in. This was believed to indicate that the cement had plugged the thief formation and had risen around the casing. The pumps were shut down for a minute and the pressure declined to 250 lb. per sq. in. When the pumps were started again the remainder of the cement was displaced with a final pump pressure of 500 lb. per sq. in., which held for sev-

COMPARE LANE-WELLS "Steelflo" ogival-point gun perforator bullets

WITH CONICAL POINT BULLETS

You can see for yourself the advantages of the new Lane-Wells "Steelflo" Ogival-Point Gun Perforator Bullets as compared with conical point bullets. These advantages, which result in greater power, cleaner perforations, deeper penetration and better producing conditions have come from field and laboratory research maintained continuously for more than eleven years.

Since the "proof of the pudding is in the eating" call Lane-Wells for your next gun perforating job and get the advantages that Lane-Wells alone can give you.

CHECK THESE FACTORS
STRENGTH OF POINT
The outline shape of the ogival-point produces a thicker extreme point of greatly increased strength. No chips break off to deflect the course of the bullet or affect penetration.
LENGTH
The ogival shape permits a shorter bullet of the same weight and thus provides a greater distance of travel when the base remains the same.
CENTER OF GRAVITY
The center of gravity is forward to keep the bullet traveling in a straighter path.
PERFORATION
The ogival-point flows displaced metal back into a tight bead to produce a cleaner perforation with less danger of damage to tools run after perforating.

FIGHTING *Tomorrow's Tools-Today!*

LANE WELLS COMPANY

Factory, General and Export Offices:
5610 South Soto Street, Los Angeles
Houston Oklahoma City
30 Branches • 24 Hour Service

eral minutes before the line was disconnected. Displacement was accomplished with 1770 cu. ft. of mud, the plugs not being bumped as some cement was to remain in the casing.

To make certain that the cement reached the desired height behind the casing a temperature survey was run. As shown in Fig. 4, the top of the cement was indicated at 1975 ft. and the top of solid cement at 2625 ft. This was a considerable distance above the troublesome zones and showed that the lost circulation and gas zones had been sealed off satisfactorily.

☆ ☆ ☆

Fig. 2. Angle of repose tests made on slow set cement (1400 surface area) pre-mixed with 3 per cent prepared bentonite

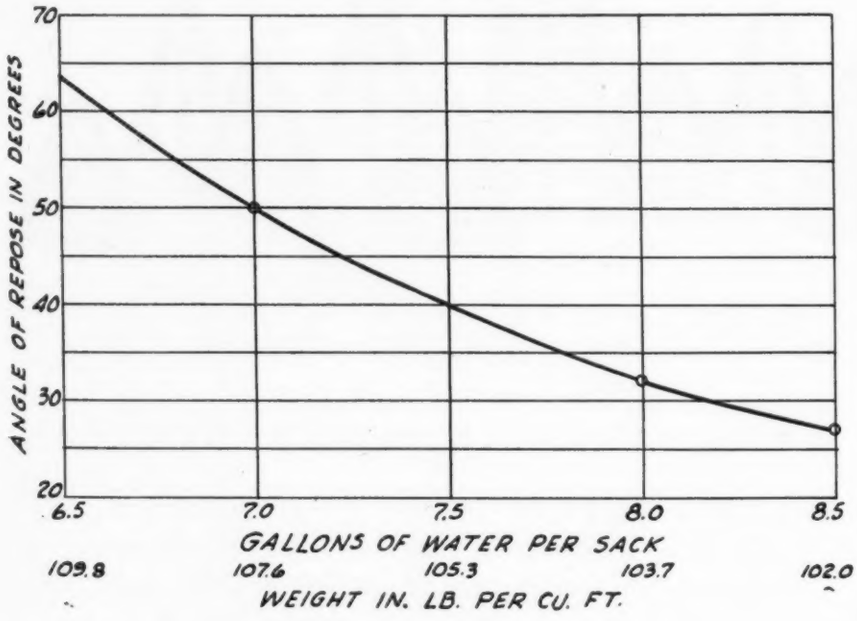
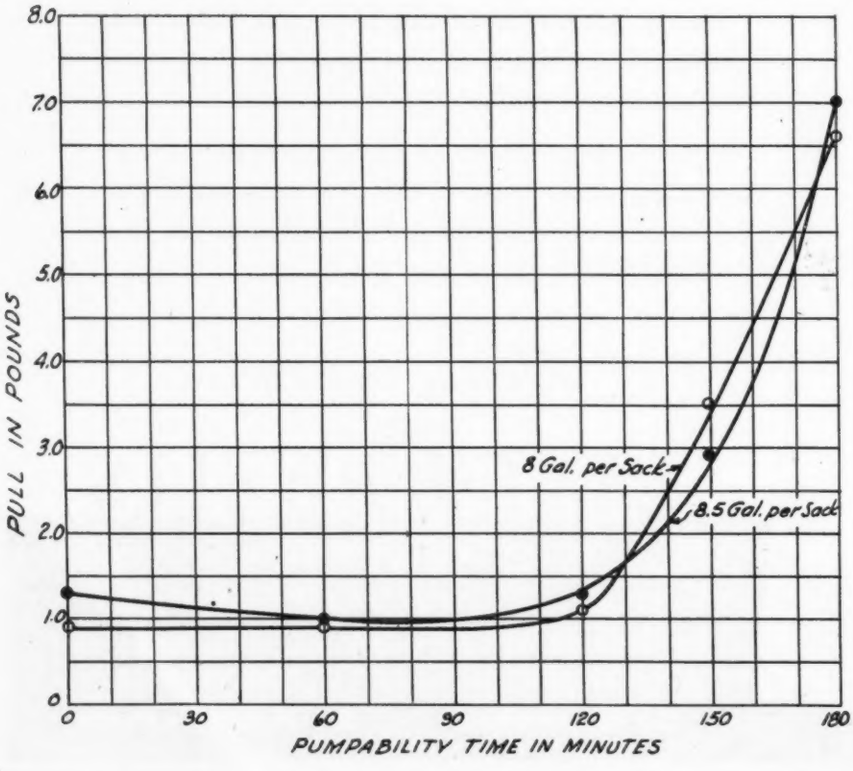


Fig. 3. Consistometer tests made on slow set cement (1400 surface area) pre-mixed with 3 per cent prepared bentonite



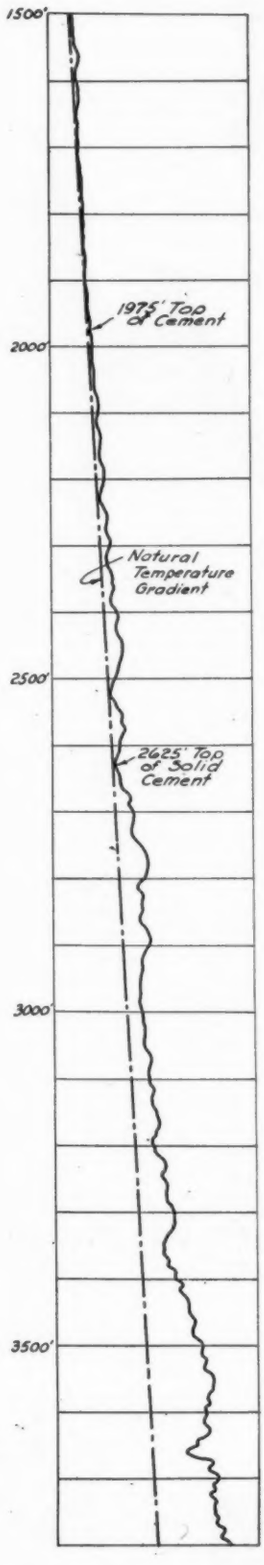
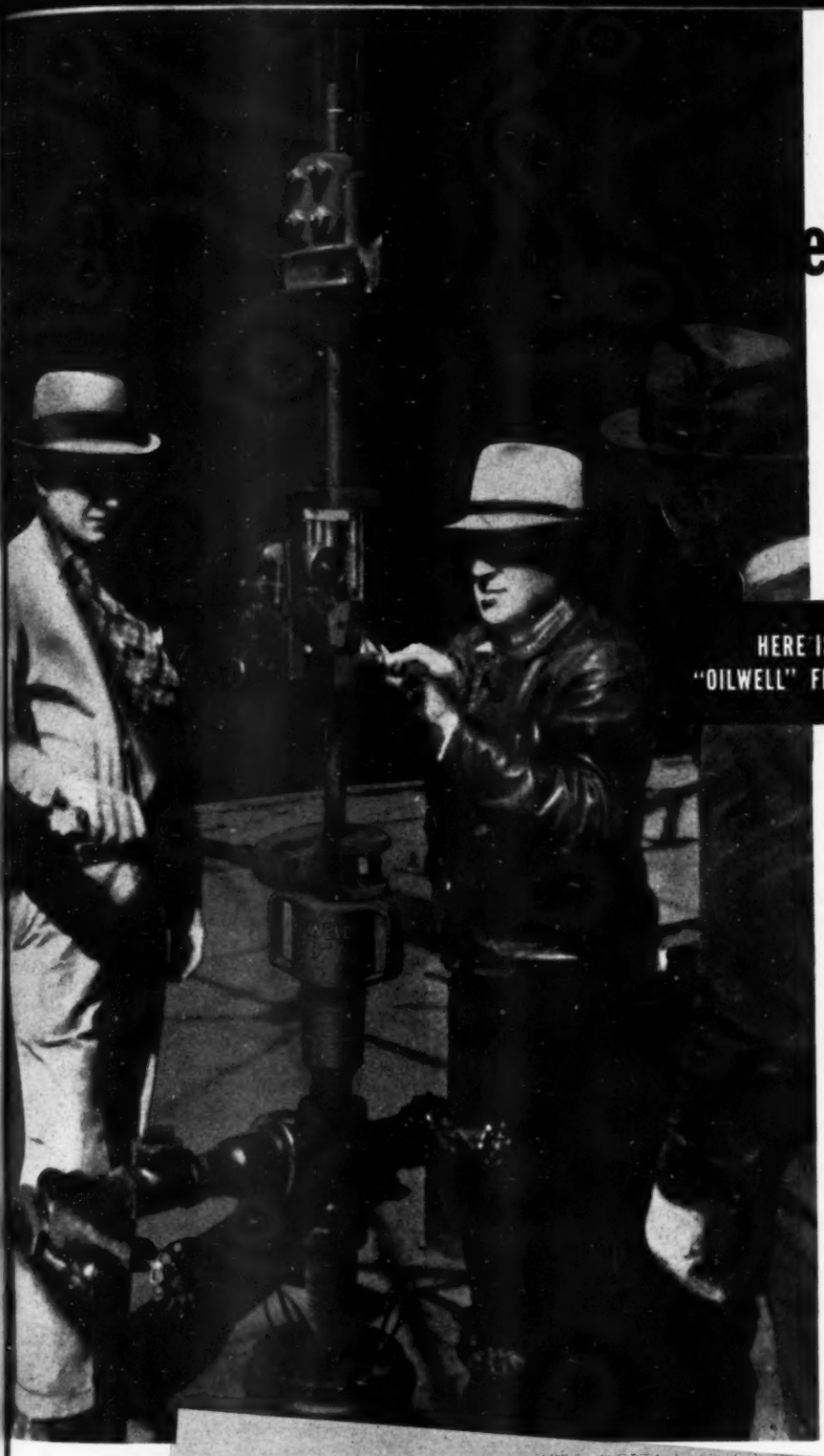


Fig. 4. Temperature survey to locate top of cement



eer found the answer to a pumping problem

HERE IS A TYPICAL EXAMPLE OF HOW "OILWELL" FIELD ENGINEERING SERVICE WORKS

FREQUENT rod breaks in a number of 5400-ft. wells were causing an Oklahoma producer no end of trouble, interrupting production and necessitating costly fishing jobs. There was no indication that the ¾-inch sucker rods were overloaded; but the fluid level was known to be low, and there was evidence of some bottom-hole difficulty.

At the request of the manager of a nearby "Oilwell" store, an "Oilwell" subsurface equipment engineer called on the producer and made a careful analysis of the pumping characteristics of the wells. Weighing the wells with a dynamometer, which accurately records pumping conditions not perceptible to eye or touch, indicated that the pumps were pounding fluid, setting up a vibration which caused the premature rod failures.

Discussing his analysis of the problem with the producer, the "Oilwell" engineer showed how the trouble could be remedied by changes in operation. The producer followed the engineer's recommendations with the result that sucker rod failures have been avoided with no decrease in production.

Field engineering service is just one of the *plus* values you get under "Oilwell's" 10-Point Supply Service. Study the others. It will pay you to deal with "Oilwell"—where your business is appreciated.

WHAT YOU GET FROM "OILWELL" 10-POINT SUPPLY SERVICE

1. Dependable source of supply
2. World-wide distribution
3. Adequate warehousing to protect material and to speed deliveries
4. Convenient store locations
5. Field engineering assistance
6. Product design and metallurgy keyed to your needs
7. Extensive manufacturing and testing facilities
8. Highest grade supplies for oil and gas field needs
9. Prompt and understanding credit service
10. 82 years of practical experience.

Steel needs more scrap NOW—

Send it in!

Army-Navy "E"—Imperial Works. Maritime "M" and Victory Fleet Flag—Wilson-Snyder Manufacturing Division.

OIL WELL SUPPLY COMPANY

Gamma Ray Logging in East Texas

Exclusive

☆ Recompletion of wells in best pay sections reduces water and increases oil production

by John L. P. Campbell
Lane-Wells Company

GAMMA ray surveys are playing an increasingly vital role in the East Texas field. Wells that might have been abandoned a few months ago are now continuing as a source of revenue to the operator as a result of such surveys.

As water gradually encroaches on the field from the west, many operators are beginning to realize that the gamma ray survey should be included in the workover estimate. The survey itself, in many cases, is the first authoritative information and reference record of the stratigraphy in the well bore. From the number of surveys already made, it is obvious that pipe line oil is cased off in many wells, and that with proper workover procedures, water encroachment into such wells may be temporarily eliminated.

True, many wells are producing from open hole, and others through screens and perforated liners. In most cases, however, where an electric log was not run before completion, the formations penetrated are not properly recorded. Gamma ray surveys substantiate or correct the records, and in so doing, include information on the casing program.

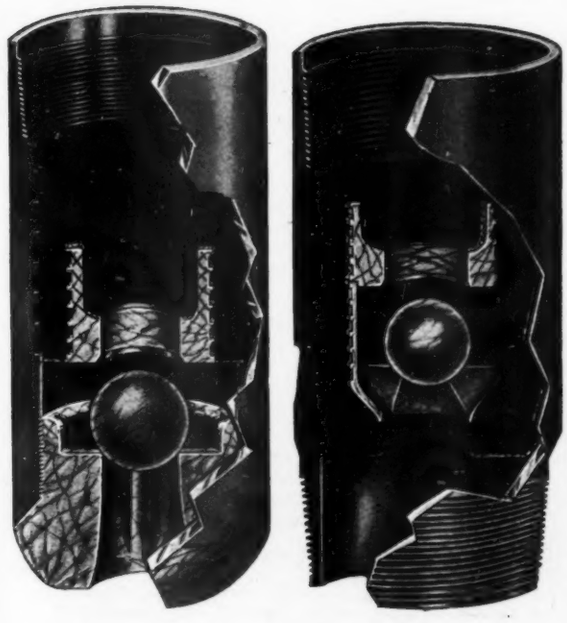
It is not difficult to understand why this is possible. Radioactivity is the basis of the survey. Radioactivity is the change of one element into another by disintegration, and these changes leave the element as a newer element of lower atomic weight. So it continues in a declining action until the end product is reached. This end product is lead and is non-radioactive. While the elements are disintegrating, rays are emanating from them (alpha, beta, and gamma), the most powerful of which is the gamma ray. Gamma rays are electromagnetic waves, similar to light waves, but having a shorter wave length and extremely high penetrating power. It will penetrate casing, cement, fluid, and the instrument of survey. When the gamma rays penetrate the surveying instrument, they ionize a gas and permit the flow of a current to the central electrode. One ten-trillionth of an ampere is the order of magnitude of the current. Because it is so minute, it is amplified within the instrument, sent to the surface by a single conductor cable, where it is further amplified and recorded. The number of gamma rays penetrating the instrument at any instant cause increases or decreases in the intensity of the current in the ionization chamber. Then changes in intensity are recorded and so become available for interpretation. Sands, for example, are of low intensity because they are weakly radioactive. Limestones, likewise, are weakly radioactive. Shales are high in radioactive intensities. Other sedimentary formations are correspondingly interpreted either through experience or by local conditions. Its use, then, in oil well information is logical. All terrestrial formations have some measurable amount of radioactivity. Therefore, any sediment can be surveyed whether it is sand, lime, shale, salt, anhydrite, potash, coal, bentonite, or another mixture. There is no formation that cannot be surveyed and interpreted. This "nut shell" information on radioactivity is applied and interpreted as a tool for workover operations in the East Texas field.

John L. P. Campbell was graduated from Cornell University in 1936, receiving a degree in geology—He was employed by Cities Service Oil Company and worked in the oil fields of Oklahoma, Kansas, West Texas, and New Mexico—During 1939, while with the Seaboard Oil Company as geologist, he worked in Illinois and Indiana—In 1940, while employed by Well Surveys, Inc., he was in charge of a radioactivity unit, running surveys in the Mid-Continent and Gulf Coast areas—Is now in the employ of the Lane-Wells Company, serving as geologist and engineer for the Gulf Coast Division, with headquarters in Houston.

Application and Interpretation

Fig. 1 is a survey in Upshur County, and is particularly adaptable as an illustration because the entire section was logged through one string of casing. As the Woodbine sand is the only pay in the field, the section below 3500 ft. in the figure is particularly important. The Austin chalk is dense and low in gamma ray intensity, and this characteristic curve, except for varying thicknesses in many wells surveyed, is easily recognized. Between the base of the Austin chalk and the top of the Woodbine sand is a definite shale break, noted by high gamma ray intensities. The Woodbine sand is low in intensities, lower than chalk, and its comparison proved by examination of the curve. The two thin zones of higher intensities in the Woodbine sand itself are caused by ash or silt. Ash is highly radioactive, such that any small amount in the sand will cause increased intensity. The higher the gamma ray intensity, the greater the amount of deposition. In this figure, the higher intensities are relatively small, so any fluid migration to the uppermost part of the sand would not be inhibited by the ash present. Workover operations on this well included a plug-back to the ashy sand below the top of the Woodbine. Although there was no material increase in oil production because of proration, the fluid production was decreased due to the elimination of bottom hole water.

Fig. 2 has three important features. Of prime importance is the survey made through casing. In this case a liner on the bottom overlapping the oil string in the chalk section was surveyed. With the gamma ray survey the operator does not have to pull the liner, nor condition the well. The overlap section from 3425-93 ft. is "dampened" due to two strings of pipe, perhaps not materially, but effectively, for this sectional comparison together with that in Fig. 1 or Fig. 3, which were run in one string, proves the point of issue. The second feature is the Eagleford shale section. In the Gladewater area the Eagleford shale is present, but pinches out to the east at the unconformity contact. The Eagleford shale is highly radioactive and a definite marker in interpretation. As sands and chalk are weakly radioactive, and the Eagleford highly radioactive, a clear picture of stratigraphy is pre-



To performance alone can be attributed the remarkably accelerated demand for Larkin equipment.

Strength of materials . . . Excellence of design . . . and infinite care in manufacture make possible the unfailing performance so vital in the deeper drilling of today.

Full Details in Your Composite Catalog

LARKIN

LARKIN PACKER CO., INC.

St. Louis, Mo.

WAREHOUSES: Houston, Corpus Christi, Odessa, Shreveport, Tulsa, Great Bend, Salem. EXPORT: 74 Trinity Place, New York City

sented. The third feature proves the use of cased hole logging. The sand above the known top of the Woodbine was not recorded by the driller. A screen, however, was set below the casing. The production allowable was met by pumping 271 bbl. of fluid. The well was plugged back to 3555 ft., blanking off the Woodbine sand completely, the shale above, and into the base of the upper sand. Production tests were most gratifying for the well has pumped pipe line oil, and no water ever since. Attention is again called to the comparative intensities of sand and chalk, because both were run in one string of pipe. Sand again has a lesser radioactive intensity than chalk.

Fig. 3 is the log of a well near Gladewater, surveyed in both open hole and casing. The casing is set in the base of the chalk, and as such, "dampens" the Austin Dense to appear of similar intensity with the Woodbine. Surveying both uncased and cased sections of a well, as in this example, three specific advantages are obtained:

1. A continuous stratigraphic log of the well bore is presented. It is accurate regarding thickness of formations, and shows the relationship of the producing section to the casing program.

2. The fluid condition of the well is immaterial. The survey can be run in oil, fresh or salt water, mud, or any mixtures of the latter, dry or partially dry.

3. Operating costs are reduced. Because of No. 1 and No. 2, the necessity of hauling and spotting fresh water over the section to be logged is eliminated. This saving voluntarily eliminates infiltration of water in the sand.

Power in 9 Octanes

"If we are to win the war we must have 100-octane in amounts that would have seemed fantastic two years ago . . . One thousand four-engine bombers, flying to an objective 1,000 miles distant, can carry 5,000,000 more pounds of bombs than can be carried if 91-octane were used."

—Petroleum Administrator Harold L. Ickes.

More important is the time and expense saved through swabbing, for the load remains undisturbed in the well.

The surveys to date are extremely informative to the operators for they not only present an authoritative record of the past and present, but establish a permanent reference zero as stated upon the logs for any future program.

Gamma ray surveys, of course, are not individual. They can be correlated with one another over short or long distances, and because the gamma ray curve is similar to the potential curve of an electric log, additional information can be derived.

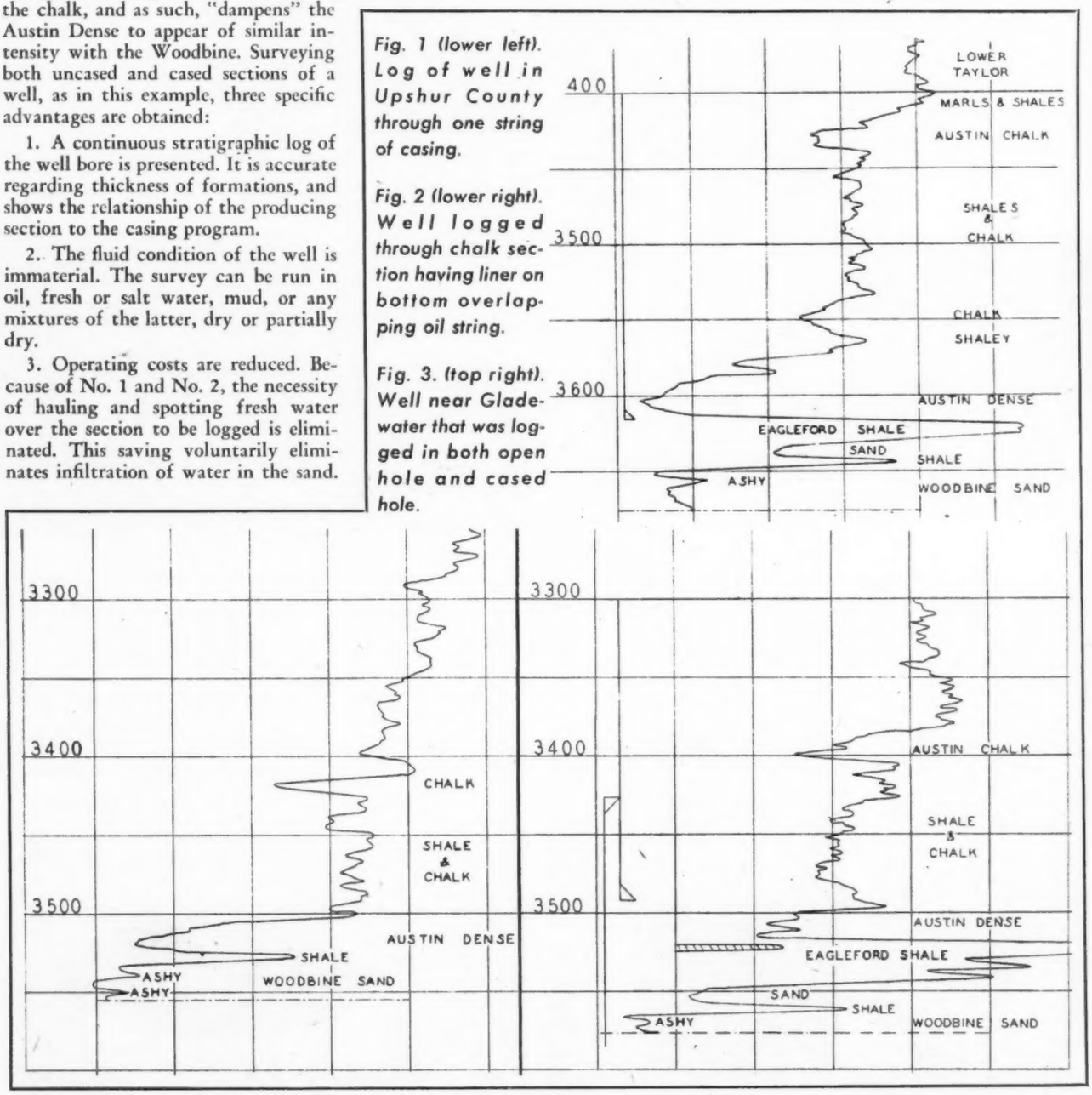
This survey is an asset to the geological and production statistics in the East Texas field. The haste to drill and produce the field, the erroneous reports, and poor casing programs, are all brought to light in presenting a continuous interpretative "wiggle"—the gamma ray curve.

☆ ☆ ☆

Fig. 1 (lower left). Log of well in Upshur County through one string of casing.

Fig. 2 (lower right). Well logged through chalk section having liner on bottom overlapping oil string.

Fig. 3. (top right). Well near Gladewater that was logged in both open hole and cased hole.



BLOCK SELECTIONS
from the
McKISSICK CATALOGUE

★ *Buy* MORE WAR BONDS

Here are just a few of the many popular McKissick Safety Blocks illustrated and described in our catalog.

Catalog on Request

McKISSICK PRODUCTS CORPORATION
TULSA, OKLAHOMA

Wellhead Pressure Reduced By Subsurface Regulation

☆ Triple installation in a Louisiana well reduces pressure from 5650 to 900 lb. per sq. in.

by John O. Farmer
Field Engineer, Otis Pressure Control, Inc.

REDUCTION of pressure by multiple staging of subsurface regulators in extremely high pressure wells has been tested successfully in the George H. Echol's Realty Operator's well No. 2, on a salt dome structure in St. James Parish, Louisiana. Subsurface regulators—usually single stage operating at pressures between 1000 and 3000 lb.—had been placed in more than 900 wells throughout the nation prior to the time multiple staged regulation was attempted in the George H. Echol's Realty Operator's well No. 2. Some progress had been made with dual installations, but as no consideration had been given to triple installations, the favorable results obtained in this well have been gratifying.

Because the maximum pressure reduction that can be effected by single stage regulation is 1500 lb. per sq. in., the reduction of subsurface pressures exceeding 3000 lb. per sq. in. to safe flowing pressures within non-freezing limits requires two or more regulators.

The George H. Echol's Realty Operator's well No. 2 was completed September 13, 1943, with perforations at an approximate depth of 9350 ft. The shut-in pressure at the surface was approximately 5650 lb. per sq. in., which required a total pressure reduction of 4200 lb. per sq. in. for safe workable limits in which hydrates would not form in the flow lines. Three 2½ in. subsurface regulators with ⅜ in. Kennametal valves and valve seats were installed at depths of 6250, 5000, and 3750 ft. The regulators were set in the conventional manner by means of an ordinary steel measuring line. The regulator set at a depth of 6250 ft. was adjusted to accommodate a pressure differential of 1500 lb. per sq. in., the regulator at 5000 ft. was set for a differential of 1400 lb. per sq. in., and the regulator at 3750 ft. was set for a differential of 1300 lb. per sq. in. After opening the wellhead connections for the desired rate of flow, the flowing pressure on the tubing stabilized at 900 lb. per sq. in., and since then the well has flowed almost continuously to supply fuel for a drilling rig. The well has produced without interruption and its general behavior has simulated that of a low pressure flowing well.

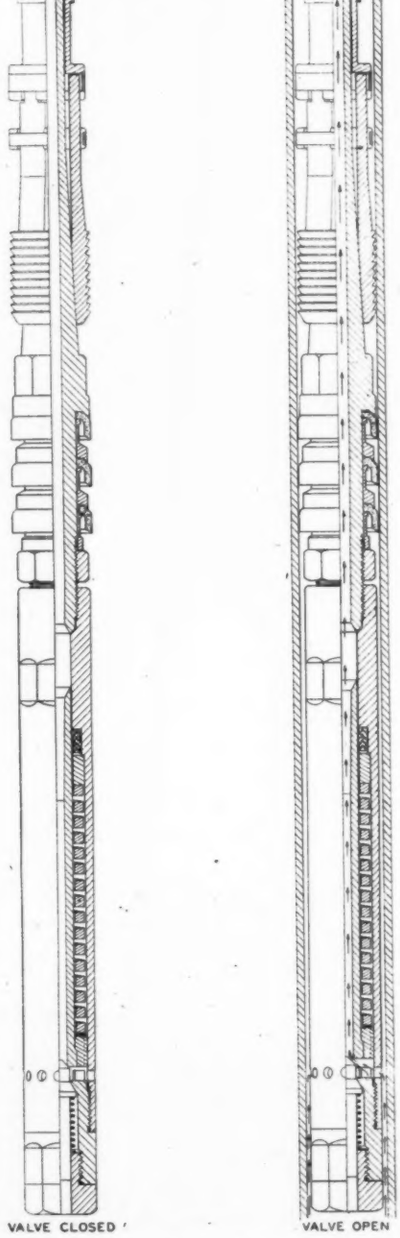
Variable Rates of Flow

Variable rates of flow, under a substantially constant low delivery pressure, can be obtained with triple regulator installations simply by varying the diameter of the orifice in the surface choke. The regulators respond automatically and instantaneously to this change—the response depends entirely upon the diameter of the surface choke used. The large the surface choke employed the wider the regulators open and the greater the resulting rate of flow. Conversely, installation of a smaller choke at the surface causes the subsurface regulator valves to move to positions permitting less flow.

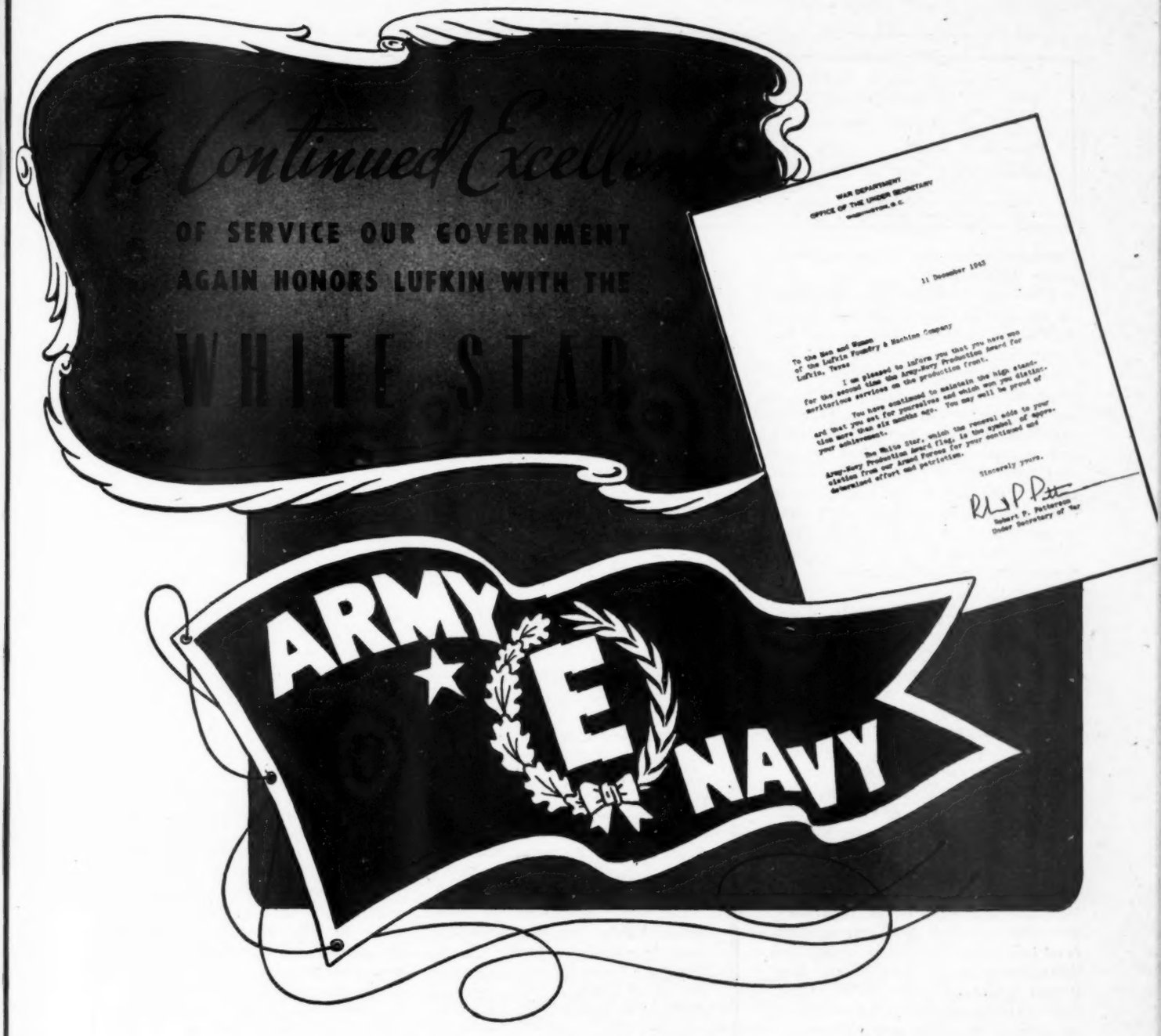
A ¼ in. surface choke is being used in the George H. Echol's Realty Operator's well No. 2 to produce approximately 1,500,000 cu. ft. of gas per day, and about 43 bbl. of condensate is recovered daily at this rate of flow. Although this well has not been flowed at higher rates for any length of time, the maximum withdrawal under this low delivery pressure should approach 8,000,000 cu. ft. per day.

Freezing Obviated

Apparently, the installation of the three regulators has obviated completely all difficulties caused by freezing, as no indication of hydrate formation has been observed in the surface controls or flow lines. This, of course, was predetermined by adjusting the regulators for the desired differentials, and by setting each regulator at a selected depth where the subsurface temperature was sufficiently high to offset the



Left—Sectional view of regulator Right—Cross-sectional view of regulator and tubing showing flow of the gas


for Continued Excellence
OF SERVICE OUR GOVERNMENT
AGAIN HONORS LUFKIN WITH THE
WHITE STAR
WAR DEPARTMENT
OFFICE OF THE UNDER SECRETARY
WASHINGTON, D. C.
11 December 1943
To the Men and Women
of the Lufkin Foundry & Machine Company
Lufkin, Texas
I am pleased to inform you that you have won
for the second time the Army-Navy Production Award for
meritorious services on the production front.
You have continued to maintain the high stand-
ard that you set for yourselves and which won you distinc-
tion more than six months ago. You may well be proud of
your achievement.
The White Star, which the renewal adds to your
station from our Armed Forces for your continued and
determined effort and patriotism.
Sincerely yours,
Robert P. Patterson
Under Secretary of War
ARMY
E
NAVY

As a mark of appreciation to our employees, we are proud to display the added star to our Army-Navy "E" pennant—the mark of continued excellence in the production of war goods.

Lufkin "Know-How" will continue until victory is ours, for we have dedicated ourselves to the number one task of this nation—*more production—better production*—our very best shall be given to this end.

Though we are still in production, on a "round-the-clock" 24-hour basis, producing *tank gears, ship gears, gun carriages,* and *truck-trailers* for our armed forces, we are also producing considerable quantities of Lufkin oil field pumping equipment.

LUFKIN
PUMPING UNITS

LUFKIN FOUNDRY & MACHINE COMPANY • LUFKIN, TEXAS

TABLE I

	1st regulator (set at 6250 ft.)		2nd regulator (set at 5000 ft.)		3rd regulator (set at 3750 ft.)	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Pressure, lb.*	5370	3870	3750	2350	2275	975
Temperature, °F.†	183	129	164	110	145	91

*Assuming gravity of 0.51 for column of dry gas in tubing.
†Assuming geothermal gradient of 1°F. for each 66 ft. of depth.

temperature loss due to gas expansion across the regulators.

The critical problem in making such an installation lies in selecting proper depths for each regulator so that the upstream temperature of the flow stream at each regulator is high enough to permit each pressure reduction without the formation of hydrates. Previous experience in setting bottom-hole chokes and regulators had established the fact that from 500 to 1000 ft. of vertical travel in the flow stream is adequate to equalize the temperature of the hydrocarbon fluid with the surrounding formation after its temperature has been reduced by a subsurface control.

As no bottom-hole temperature surveys had been made on this well, a reservoir temperature of about 230° F., or approximately the same temperature as that observed in deep-seated salt dome structures of similar depth, was assumed. By making this assumption, the calculated upstream and downstream pressures and temperatures at each regulator were as shown in Table 1.

The temperature drop across each regulator is 54° F.; yet the upstream temperature in each instance is sufficiently high to permit the temperature loss without even approaching freezing conditions. The total temperature loss across all three regulators, therefore, is 162° F. If all pressure drop occurred across the surface choke, the downstream temperature of the flow stream would approach minus 82° F. and would require the use of an elaborate surface heater to prevent freezing in the surface controls.

Maximum Safety Factor

The tremendous potential energy and destructive power in a well having a surface pressure of 5650 lb. per sq. in. can be realized to some extent when one considers that this pressure is comparable to that built up in the barrel of a 30-06 army rifle when it is discharged. Although the instantaneous pressure in the cartridge is considerably greater than 5650 lb. per sq. in. a comparable pressure exists in the barrel after the projectile begins moving forward. The safest and most practical way to produce a well with such high pressure is to control or regulate these tremendous pressures at a safe subsurface depth and not permit them to exist at the surface.

To produce a well with a surface pressure of 5650 lb. per sq. in. without the aid of subsurface controls would require elaborate and expensive surface heaters, continuously supervised, the operation of which is both hazardous and costly.

Conclusion

The results obtained from this first triple subsurface regulator installation are considered quite satisfying. The regulators were installed in the conventional manner, demonstrating that subsurface regulators can be installed safely with a wire line in wells having surface pressures in excess of 5000 lb. per sq. in. In three months' continuous operation, no servicing has been needed as no trouble has been encountered. Undoubtedly, the use of durable monel valves and seats with Kennametal inserts is responsible to a great extent for the absence of trouble from corrosive or abrasive flow action.

The operation in general proves further that, provided there is sufficient bottom-hole temperature, multiple staging of subsurface regulators is the most practical and safest means of handling high pressure wells, and may become the adopted method of producing other wells in this category in the future.

☆ ☆ ☆

MATERIALS RESTRICTIONS RELAXED

Acting to encourage further the oil industry's efforts toward increasing the nation's petroleum supply, the Petroleum Administration for War has announced the relaxation of certain restrictions—as much as the present situation will permit—on the use of critical materials in crude oil production and natural gas and natural gasoline operations.

Action was taken in an amendment of a formal order (Petroleum Administrative Order No. 11), which became effective January 1, 1944.

Discussing the significance of the amended order, Petroleum Administrator Harold L. Ickes, said, "The relaxation of certain restrictions on the use of material will permit oil operators to utilize critical items on a slightly larger scale than has heretofore been possible. Present conditions warrant the use of these materials, particularly in view of the pressing need for the utilization of every facility that may encourage efforts to increase the production of crude oil in the United States."

Salient new features of the amended order are as follows:

(1) In drilling for oil on sectionalized land within two miles of any other drilling or producible well, the well shall be located on the quarter-quarter section within 150 ft. of the pattern well location and at least 300 ft. from quarter-quarter section lines.

(2) The minimum distance requirement between wells on 40-acre spacing has been reduced from 990 ft. to 900 ft. This will provide greater flexibility to operators in locating wells on the drilling unit.

(3) Unless specifically prohibited by an exception or supplemental order, any well may be reworked or plugged back and recompleted in a shallower pool penetrated by the well. This provision applies throughout the United States except in California where the conditions under which wells may be reworked or plugged back are covered by Supplementary Order No. 4.

(4) Any well may be deepened and recompleted in a deeper pool if the well, with respect to the pool or pools in which it is recompleted, conforms to the quarter-quarter section or 40-acre spacing requirements of the order, except that a pattern location need not be followed.

(5) Pumping or other artificial lifting equipment may be installed on wells that have been deepened to lower pools pursuant to the order, and it may be interchanged in its entirety between wells on the same lease. Additional tubing or sucker rods may be installed on any pumping wells.

(6) Condensate fields are included within the newly defined term "restricted area." Drilling of all wells in "restricted areas" must be by exception unless commenced prior to designation of the area as a "restricted area."

(7) Gas gathering systems may be constructed provided material cost does not exceed $5000 and existing facilities are not duplicated.

THE *Petroleum* Engineer's CONTINUOUS TABLES

A DAILY REFERENCE FOR OPERATING MEN

INSTALLMENT NO. 79

A VALUABLE and regular feature of *The Petroleum Engineer,* the Continuous Tables, now in their seventh year of publication, were designed to save time and effort for the technician and the practical field or plant worker. The tables have proved one of the most popular and helpful departments of *The Petroleum Engineer.* Data are presented in the simplest form available with many types of information included that are best presented by curves or nomographs when three or more variables must be considered simultaneously. More than 450 tables have been published.

The Continuous Tables have developed as a result of suggestions for new tables, direct contributions, and improvements to existing tables by members of the petroleum and related industries, including manufacturing concerns, who are continually searching for practical information reduced by computation to tabular form readily applicable to the problems daily confronting them that might otherwise necessitate a more or less tedious calculation. These contributions and suggestions from the industry have resulted in a valuable exchange of information and data contributing to the progress of the industry as a whole.

To readers of *The Petroleum Engineer,* who are only now becoming interested in the Continuous Tables, it should be pointed out that each table is assigned a filing or index number that conforms with the Dewey Decimal System of classification as modified and extended for the petroleum and related industries by L. C. Uren, professor of Petroleum Engineering at the University of California. This complete index has been published in earlier installments of the tables and is now available in booklet form at a cost of 50 cents per copy from *The Petroleum Engineer,* P. O. Box 1589, Dallas, Texas. Complete sets of the tables from the first installment to the present are also available in conjunction with subscriptions at the rate of $3.00 a year, or $4.00 for two years. General field classification numbers are as follows:

Nos. P000-P399—General

Nos. P400-P-499—Drilling

Nos. P500-P599—Production

Nos. P600-P699—Transportation and storage (includes pipe line)

Nos. P700-P799—Refining, including

Nos. P770-P799—Natural Gasoline, which may be classified in a separate division as shown here if of special interest to the user

INDEX TO TABLES*

Title of Table		Index No.	Page	Issue
Electrical terms and formulae		P 062.1	157	Sept.
Psychrometric chart		P 066.0	153	Nov.
Properties of round welded carbon steel tubes	(sheet 1)	P 094.113.1	103	July
Properties of round welded carbon steel tubes	(sheet 2)	P 094.113.1	141	Aug.
Hydrocarbon fluid densities		P 213.100.1	147	Aug.
Hydrocarbon liquid densities		P 213.100.1-B	151	Oct.
Density of methane and ethane systems		P 213.100.101.	161	Nov.
Density of liquid normal paraffins		P 213.100.2	161	Sept.
Density of ethane		P 213.100.3	153	Sept.
Density of normal butane		P 213.100.4	163	Sept.
Density of normal pentane		P 213.100.5	155	Oct.
Density of propane		P 213.100.6.	151	Nov.
Relation of pseudo critical temperature and pressure to gas gravity		P 214.000.	171	Jan.
Reid vapor pressure versus initial vapor pressure		P 214.210.	129	Dec.
Viscosity of paraffinic hydrocarbon gases at atmospheric pressure		P 215.000.	157	Nov.
Viscosity of paraffinic hydrocarbon liquids at atmospheric pressure		P 216.1.	159	Nov.
Viscosity conversion chart		P 216.13	159	Sept.
Surface tension of paraffin hydrocarbons		P 216.200.	175	Jan.
Specific heat of hydrocarbon vapors at one atmosphere pressure		P 238.1	167	Jan.
Fuel consumption chart—gas, gasoline, and butane		P 422.344.	105	July
Polished rod loads		P 514.541-B	179	Jan.
Chart for approximating bottom hole pressure from wellhead pressure		P 533.400.	151	Sept.
Chart for approximating bottom-hole pressure from wellhead pressure		P 533.400-B.	155	Nov.
Valve and fitting resistance to fluid flow		P 615.1.	163	Nov.
Solution of Weymouth's formula for gas flow in pipe lines	(sheet 3)	P 621.1	173	Jan.
Gas compression temperatures and values of "N"		P 624	153	Oct.
Vapor pressures versus temperatures for motor and natural gasolines		P 640.1	107	July
Expansion of air-vapor mixtures in atmospheric storage tanks		P 640.13	101	July
Pressures of air-vapor mixtures in pressure containers		P 640.14	143	Aug.
Breathing loss from cone roof tanks with conservation vents		P 640.141.	139	Aug.
Theoretical filling loss rates for storage tanks and pressure vessels		P 640.142.	155	Sept.
Pressure extensions—orifice meter calculations	(sheet 21-A)	P 683.32	113	July
Pressure extensions—orifice meter calculations	(sheet 21-B)	P 683.32	145	Aug.
Friction of air in pipes		P 762.300.	119	Dec.
Compressibility factors for methane at reduced temperatures and pressures		P 771.001.	123	Dec.
Physical constants of hydrocarbons		P 771.001-B.	125	Dec.
Physical constants of hydrocarbons		P 771.001-C.	121	Dec.
Physical constants of hydrocarbons		P 771.001-D	169	Jan.
Constants of vapors and gases		P 771.001.1	177	Jan.
Compressibility factors for methane at absolute pressures and temperatures		P 771.002.	127	Dec.
Compressibility factors for ethane at absolute pressures and temperatures		P 771.003.	131	Dec.
Vaporization equilibrium constants for normal pentane		P 771.214.750.	109	July
Vaporization equilibrium constants for isopentane		P 771.214.755.	111	July
Vaporization equilibrium constants for normal hexane		P 771.214.760.	137	Aug.
Vaporization equilibrium constants for normal heptane		P 771.214.765.	149	Aug.

*This index will be revised monthly. The index for installments 1-12, inclusive, will be found in the May, 1938, issue; 13-24, inclusive, in the June, 1939, issue; 25-36, inclusive, in the June, 1940, issue; 37-48, inclusive, in the June, 1941, issue; 48-60, inclusive, in the June, 1942, issue, and 61-72, inclusive, in the June, 1943, issue.

INDEX TO ADVERTISERS IN TABLES

		Page	Issue	Backing Table No.
Bantam Bearings Division, The Torrington Company	(sheet 1)	104	July	P 094.113.1
Bantam Bearings Division, The Torrington Company		150	Aug.	P 771.214.765.
Bantam Bearings Division, The Torrington Company		156	Oct.	P 213.100.5
Bantam Bearings Division, The Torrington Company		158	Sept.	P 062.1
Bantam Bearings Division, The Torrington Company		153	Nov.	P 066.0.
Bantam Bearings Division, The Torrington Company		130	Dec.	P 214.210.
Bantam Bearings Division, The Torrington Company		170	Jan.	P 771.001-D
Brown Fintube Co., The		110	July	P 771.214.750.
Brown Fintube Co., The	(sheet 2)	142	Aug.	P 094.113.1
Brown Fintube Co., The		162	Sept.	P 213.100.2
Brown Fintube Co., The		160	Nov.	P 216.1.
Brown Fintube Co., The		132	Dec.	P 771.003.
Brown Fintube Co., The		176	Jan.	P 216.200.
Cook, C. Lee, Mfg. Co.	(sheet 3)	174	Jan.	P 621.1
Crane Co.		112	July	P 771.214.755.
Chapman Valve Manufacturing Co.	(sheet 21-B)	146	Aug.	P 683.32
Cummins Engine Company		158	Nov.	P 215.000.
Diamond Chain & Mfg. Co.		144	Aug.	P 640.14
Griscom-Russell Co.		152	Nov.	P 213.100.6.
Griscom-Russell Co.		124	Dec.	P 771.001.
Griscom-Russell Co.		168	Jan.	P 238.1
Hazard Wire Rope Division of American Chain and Cable Co., Inc.		106	July	P 422.344.
Hazard Wire Rope Division of American Chain and Cable Co., Inc.		140	Aug.	P 640.141.
Hazard Wire Rope Division of American Chain and Cable Co., Inc.		152	Sept.	P 533.400.
Hazard Wire Rope Division of American Chain and Cable Co., Inc.		154	Oct.	P 624
Hazard Wire Rope Division of American Chain and Cable Co., Inc.		156	Nov.	P 533.400-B.
Hazard Wire Rope Division of American Chain and Cable Co., Inc.		120	Dec.	P 762.300.
Hazard Wire Rope Division of American Chain and Cable Co., Inc.		172	Jan.	P 214.000.
Hyatt Bearings Division, General Motors Sales Corporation	(sheet 21-A)	114	July	P 683.32
Hyatt Bearings Division, General Motor Sales Corporation		138	Aug.	P 771.214.760.
Hyatt Bearings Division, General Motor Sales Corporation		164	Sept.	P 213.100.4
Hyatt Bearings Division, General Motor Sales Corporation		152	Oct.	P 213.100.1-B
Hyatt Bearings Division, General Motor Sales Corporation		164	Nov.	P 615.1.
Hyatt Bearings Division, General Motor Sales Corporation		122	Dec.	P 771.001-C.
Hyatt Bearings Division, General Motors Sales Corporation		180	Jan.	P 514.541-B
Maxim Silencer Company		108	July	P 640.1
Maxim Silencer Company		154	Sept.	P 213.100.3
Maxim Silencer Company		128	Dec.	P 771.002.
Maxim Silencer Company		178	Jan.	P 771.001.1
Midwest Piping & Supply Company		156	Sept.	P 640.142.
% Proportioneers, Inc. %		126	Dec.	P 771.001-B.
Twin Disc Clutch Company		148	Aug.	P 213.100.1
Whitney Chain and Manufacturing Company		102	July	P 640.13
Whitney Chain and Manufacturing Company		160	Sept.	P 216.13
Whitney Chain and Manufacturing Company		162	Nov.	P 213.100.101.

SPECIFIC HEAT OF HYDROCARBON VAPORS AT ONE ATMOSPHERE PRESSURE

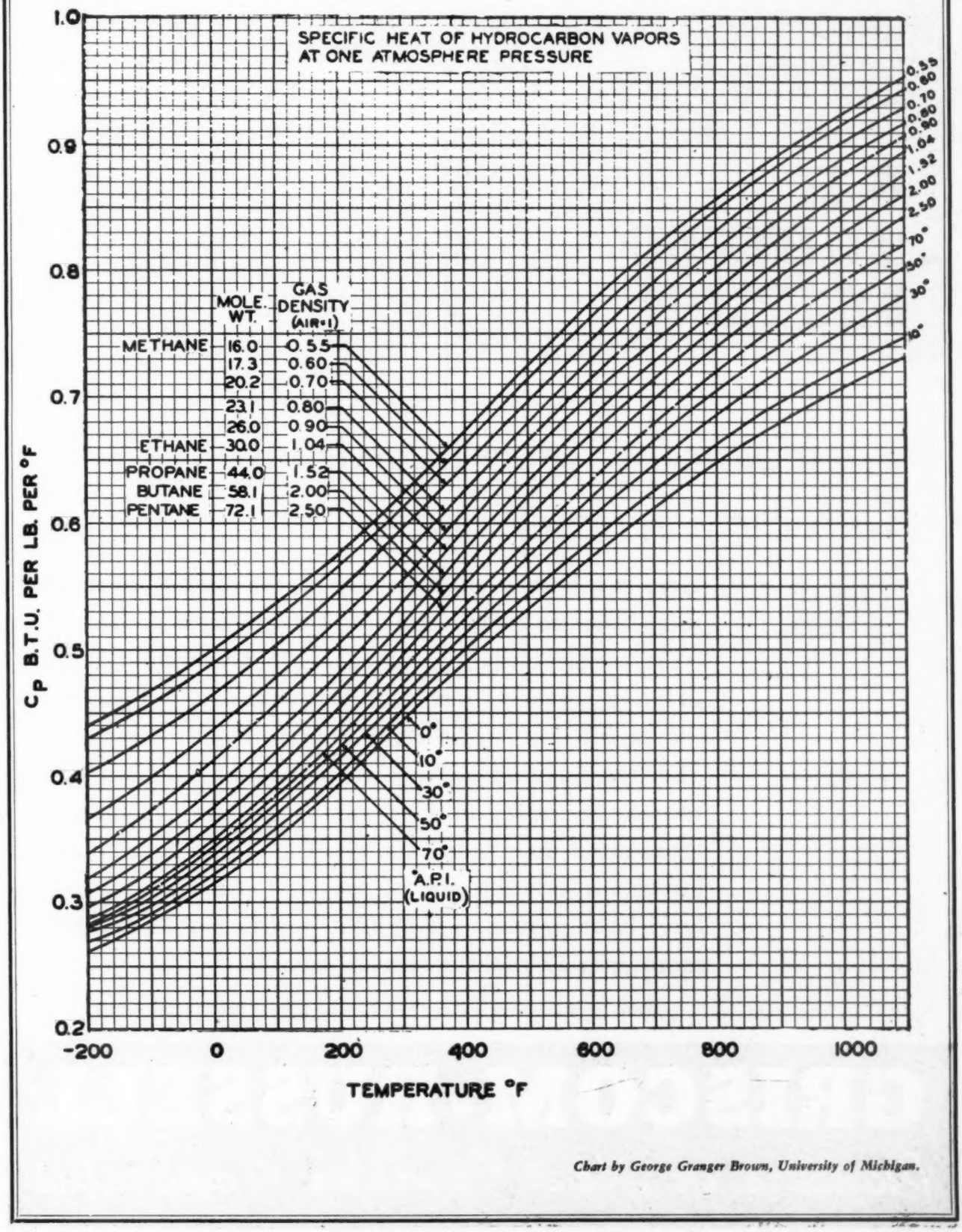
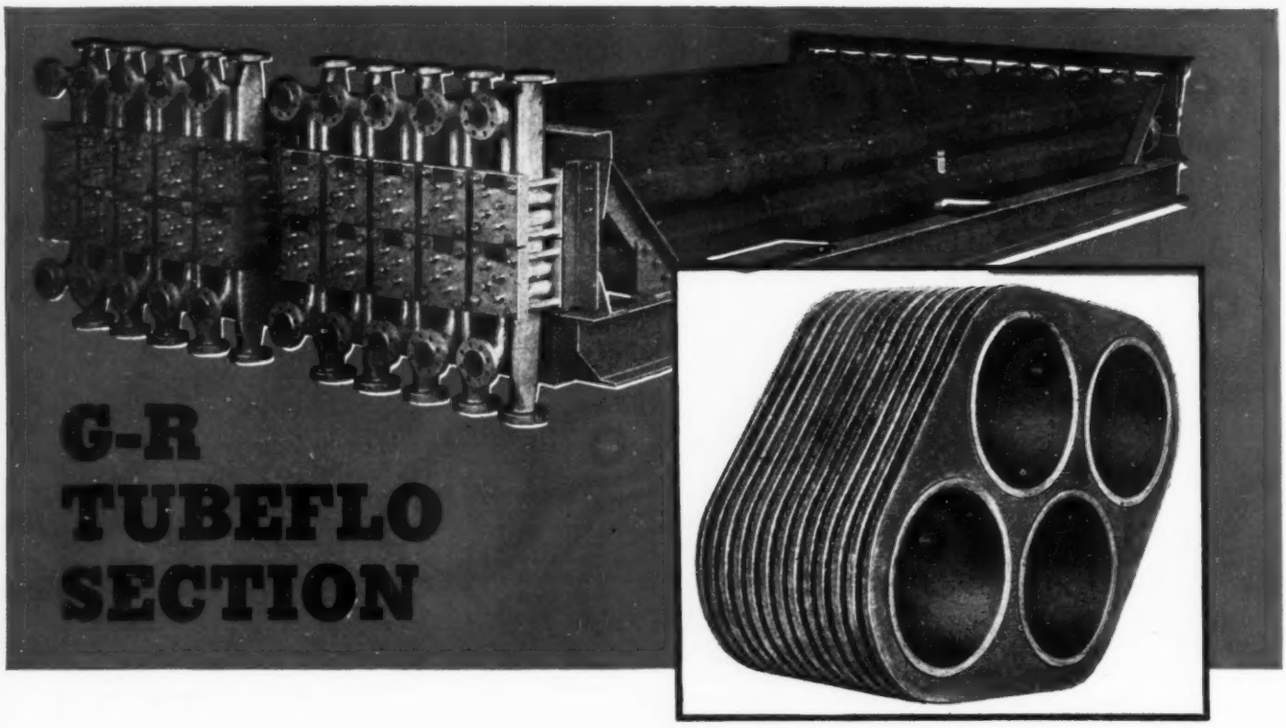


Chart by George Granger Brown, University of Michigan.



. . . maintains rated heat transfer with dirty or tarry fluids

Here is a heat exchanger that resists fouling or clogging because of the large and uniform cross-section of all passages and high velocity of flow. Contamination of fluids is positively prevented, because leakage cannot possibly occur between the two sides of the unit. The design is ideal for high pressures and temperatures, because all fluid passages are reinforced throughout their entire length. These and additional important advantages of the G-R Tubeflo Section have been proven in over 3,500 installed units and by more than 15 years of service records.

Write for Bulletin describing G-R Tubeflo Section features in detail

The Griscom-Russell Co.
285 Madison Avenue
New York 17, N.Y.

GRISCOM-RUSSELL

Pioneers in Heat Transfer Apparatus

PHYSICAL CONSTANTS OF HYDROCARBONS

Hydrocarbon	Specific gravity 20/4 °C.	M. P.	B. P.	Index of refraction n_D^{20}	Viscosity Abs. Poises	Specific heat	Heat of vaporization Cal/G.	Heat of combustion K-Cal/mol	Aniline point °C.	Coeff. of expansion °C.	Critical constants P Atm.	Critical constants T °C.	Critical constants D	Vapor pressure °C.	Vapor pressure mm.	Octane number Actual	Octane number Blending	Surface tension Flash °C.
C_9H_{20} Nonane	4.424 (air) / 0.71808	—53.7	150.7	1.4056	0.006621 (25)	0.523 (25)	66.7	1463.0p	74.9 (cst)	0.00111 (0-50)	22.8	322.8	0.232	39.6 86.7	11 100	—45m	—34r	22.91 31.1
2–Methyloctane (Isononane)	0.7134	—80.5	143.25	1.4032	0.00525 (37.8) 0.00279 (100)	....	64.0	1454.1	77.5 (cst)	.....	..	314.4	..	101.3	215	—4.0m	....	....
3–Methyloctane	0.7210	—108.0	144.18	1.4065	.....	....	64.5	1351.1	75.0 (cst)	.....	..	316.6	..	102.2	215	12.0m	....	....
4–Methyloctane	0.7199	—113.3	142.4	1.4061	.....	....	64.5	1451.1	74.5	.....	..	318.3	..	100.4	215	20.0m	....	....
2, 3–Dimethylheptane	0.7270*	—116.7 (Glass)	140.65	1.40850	0.00521 (27.8) 0.00330 (100)	....	64.0	1458.8	71.0 (cst)	.....	..	315.0	..	139.05	728	52.0m	....	....
2, 4–Dimethylheptane	0.716	....	133.3	1.4033*	.....	....	67.2	1458.8	78.0	.....	..	306.0	..	.....		60m	....	....
2, 6–Dimethylheptane	0.70894	—103.0	135.2	1.40075	.....	....	63.0	1458.8	80.0 (cst)	.....	..	306.0	..	93.4	215	31m	36r	....
3–Ethylheptane	0.7272	—114.9 (Glass)	143.1	1.4090	0.00490 (37.8) 0.00261 (100)	....	64.5	1458.8	73.0	.....	..	318.0	..	142.1	738.5	37m	....	....
2, 3, 5–Trimethylhexane	0.7222*	....	131.8—131.9	1.4051	.....	....	....	1458.8	76.0	.....	..	..	..	129	738	88m	....	21.17
2, 2, 4, 4–Tetramethylpentane	0.71957	—66.6	122.28	1.40677	0.00680 (37.8) 0.00339 (100)	....	62.0	1458.8	75.0	.....	..	295.5	..	70.6 108.9	149.4 525.8	123m	....	....
3, 3–Diethylpentane	0.7522	—40 to —42.0	139.2	1.4197	.....	....	....	1458.8	65.0	0.001044 (15-30)	..	..	..	46.2 138.1	19 740	....	....	22.92 ....
2, 3–Dimethyl-3–Ethylpentane	0.7539*	....	141.6	1.4186	.....	....	64.1	1458.8	66.0	.....	..	318.0	..	.....		54m	....	....

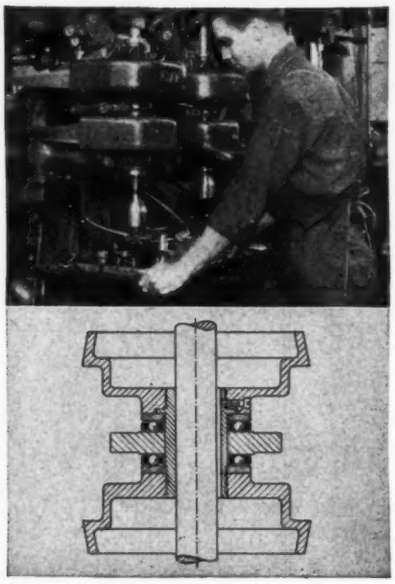
*Estimated.

See table P 771.001. B for footnotes.

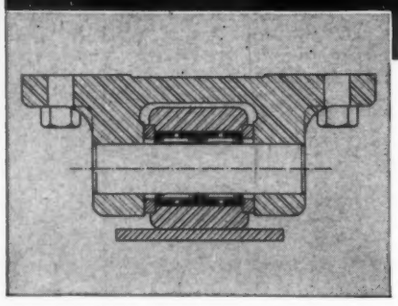
Table from "Physical Constants of the Principal Hydrocarbons," 4th edition, by courtesy of copyright owner, The Texas Company.

IN THE NEWS
WITH TORRINGTON BEARINGS

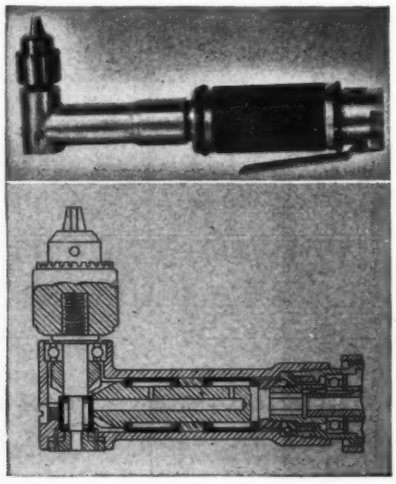
NAKED HULLS GROW INTO HUGE PBY Naval Patrol Bombers as they pass along the conveyor system of the production line at the Consolidated Vultee Aircraft Corporation. The hulls are supported on cradle-like dollies which move the ever-increasing load smoothly to its completion while removable sectional platforms provide ready access to the superstructure of the airplanes. To safeguard the vital wheel axles of the conveyor dollies so that the heavy load will be carried steadily and safely and without time-consuming stoppages, the makers of the conveyor system selected Type NCS Needle Bearings for their high capacity and low friction coefficient.



TAPPING OPERATIONS are done swiftly and accurately with this Garvin No. 2-X Duplex Automatic Tapper manufactured by the Western Machine Tool Works. The builders of this machine selected Torrington Ball Thrust Bearings for application on the spindle between the forward and reverse driving friction cones, as shown in the cross-section, because their sturdy construction and high accuracy could withstand the repeated shock loading which the application required.



"WORLD'S LARGEST" are these cold storage doors made by the Jamison Cold Storage Door Company for a 67° below zero cold chamber at Wright Field. To help support and lend ease to the operation of these colossal doors, a Needle Bearing equipped floor roller assembly has been applied to the bottom of the hinge sides, as shown in the cross-section, to provide ease of manual operation.



RIVET HOLES IN TIGHT CORNERS and small openings are easily drilled with this pneumatic angle drill made by the Chicago Pneumatic Tool Company. Because of their small size and high load capacity NCS Needle Bearings were selected to carry the load on the shaft of these compactly designed tools, as illustrated in the accompanying cross-section of the drill.

A COMPREHENSIVE LINE OF STANDARD ANTI-FRICTION Bearings—straight roller, tapered roller, needle, and ball—is offered by the Bantam Bearings Division. For new or unusual bearing problems, the assistance of Torrington-Bantam's engineers is especially valuable. Years of experience in the design and application of special bearing styles stand back of their recommendations. Whenever you need engineering counsel on standard or custom-built bearing types, TURN TO TORRINGTON.

ARMY E NAVY

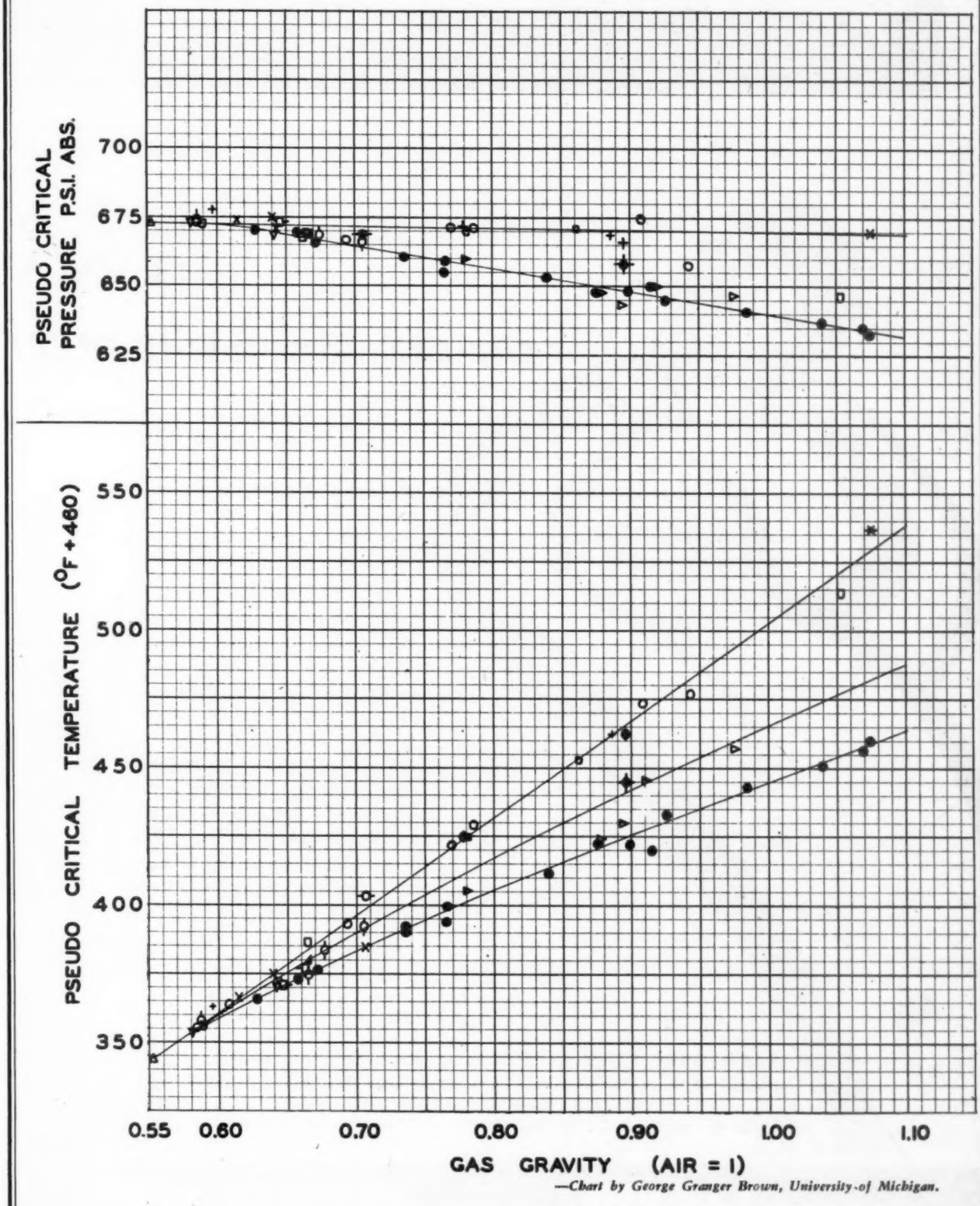
TORRINGTON BEARINGS

STRAIGHT ROLLER • TAPERED ROLLER • NEEDLE • BALL

THE TORRINGTON COMPANY • BANTAM BEARINGS DIVISION

SOUTH BEND 21, INDIANA

RELATION OF PSEUDO CRITICAL TEMPERATURE AND PRESSURE TO GAS GRAVITY



—Chart by George Granger Brown, University of Michigan.

You wouldn't handcuff a PITCHER!

LAY-SET *Preformed* IS FREE!

It is the preforming process that frees LAY-SET wire rope of self-destructive internal stresses. Being preformed, Hazard LAY-SET is not shackled by twisted strains. Rather, every wire and strand is free to do its full share of work from the very first hour it is put on your machine.

Hazard LAY-SET Preformed is a "pre-broken-in" rope; it resists kinking and snarling; it handles easier, faster, safer, and cheaper. It possesses high resistance to bending fatigue and so lasts longer—*much* longer than non-preformed wire rope. Regardless of where or how you use wire rope, whether for running or standing service, specify Hazard LAY-SET Preformed—the rope that gives you greater dollar value.

Ever since Pearl Harbor, and even before, Hazard LAY-SET Preformed has been saving time and money for the Government, the Armed Forces, and the taxpayer.

HAZARD WIRE ROPE DIVISION • Wilkes-Barre, Pa., Chicago, Pittsburgh, Fort Worth, Houston, Wichita, San Francisco, Denver, Los Angeles

Distributors in all important oil field centers

AMERICAN CHAIN & CABLE COMPANY, INC. • BRIDGEPORT, CONNECTICUT

GREEN SIGNIFIES SAFETY

HAZARD LAY-SET *Preformed* ROTARY LINES

SOLUTION OF WEYMOUTH'S FORMULA FOR GAS FLOW IN PIPE LINES

INSTRUCTIONS: Place straight-edge on P_2 on scale A and on P_1 on scale CL and read $(P_1^2—P_2^2)^{½}$ on scale B at straight edge. Place straight edge on delivery on scale CR and on $(P_1^2—P_2^2)^{½}$ on scale D and read d/L on scale EL. Place straight-edge on pipe line length on scale ER and on d/L on scale F and read pipe size on scale G.

Example: Find P_1 when P_2 is 500, delivery is 200,000 MCF, size of line is 24 in. with 0.375-in. wall thickness, and length of line is 75 miles.

Step No. 1: Place straight-edge on 23.25 on scale G and on 75 on scale ER and read d/L (367) on scale F.

Step No. 2: Place straight-edge on 367 on scale EL and on 2 on scale CR and read $(P_1^2—P_2^2)^{⅔}$ (545) on scale D.

Step No. 3: Place straight-edge on 545 on scale B and on 500 on scale A and read P_1 (740) on scale CL.

Note: For 2-in., 3-in., and 4-in. pipe read d/L as units and delivery as thousands of MCF; for 5-in., 6-in., 8-in., 10-in., 12-in., and 14-in. pipe read d/L as tens and delivery as tens of thousands; for pipe above 14-in. read d/L as hundreds and delivery as hundreds of thousands.

Based on Weymouth's formula for flow of gas through pipe lines: $Q=C\left(\frac{d^{8/3}(P_1^2—P_2^2)}{GTLm}\right)^{⅔}$.

Basic conditions: Pressure base 16.4 lb. per sq. in. Flowing temp. 60°F. Base temp. 60°F., gravity 0.70.

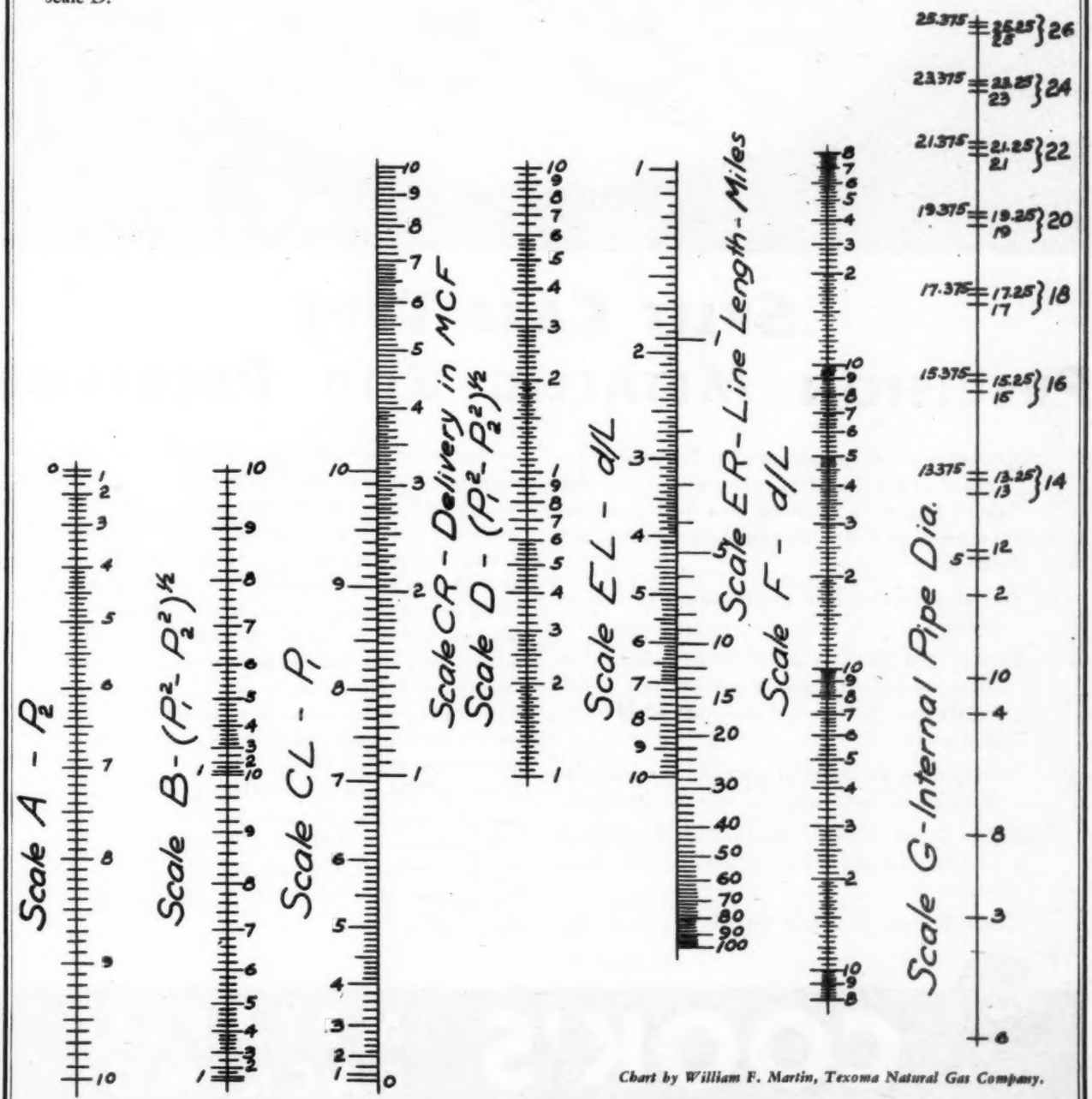
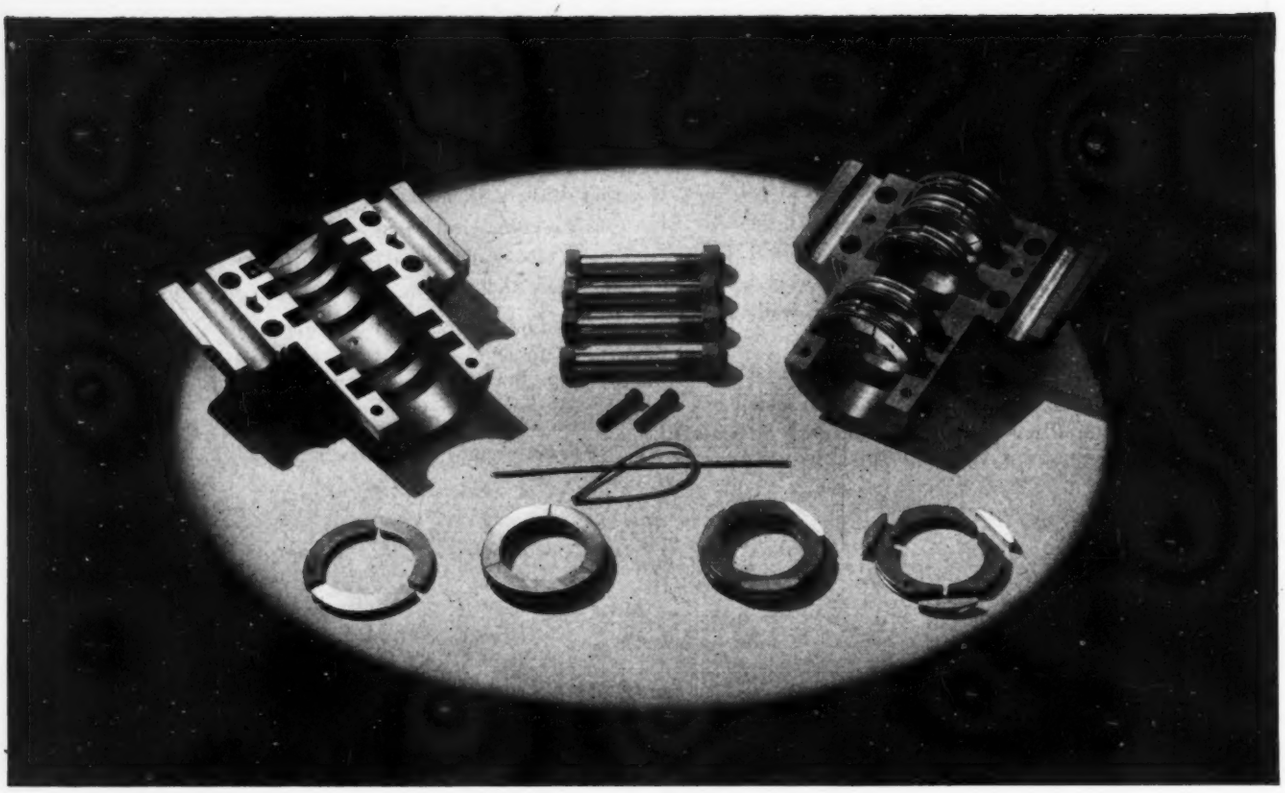


Chart by William F. Martin, Texoma Natural Gas Company.



(Unretouched Photo)

SPLIT CASE TYPE PRECISION METALLIC ROD PACKINGS

YOUR engine or compressor will deliver more horsepower at less cost if its rods are equipped with COOK'S Metallic Packings. And the reasons why are summed up in the following features of COOK'S Packings:

Precision construction assures positive seal of pressure.

Packing rings "float" in self-contained casings which allows for rod misalignment and vibration, avoiding the extra friction and wear that would otherwise result.

Packing rings are made of anti-friction metals and designed to compensate for wear automatically.

Design also provides a constant oil film between packing rings and rod, eliminating metal to metal friction.

COOK'S Packings reduce friction to a mere fraction, become a permanent part of the machine and render years of service without repairs.

Recognizing these advantages many engine and compressor manufacturers supply COOK'S Packings as original equipment; others furnish them on request. There is a proved COOK'S Packing for all prevailing pressures and temperatures in annular cup, split case and other special designs. Here is illustrated a split case packing developed for application without disconnecting the rod.

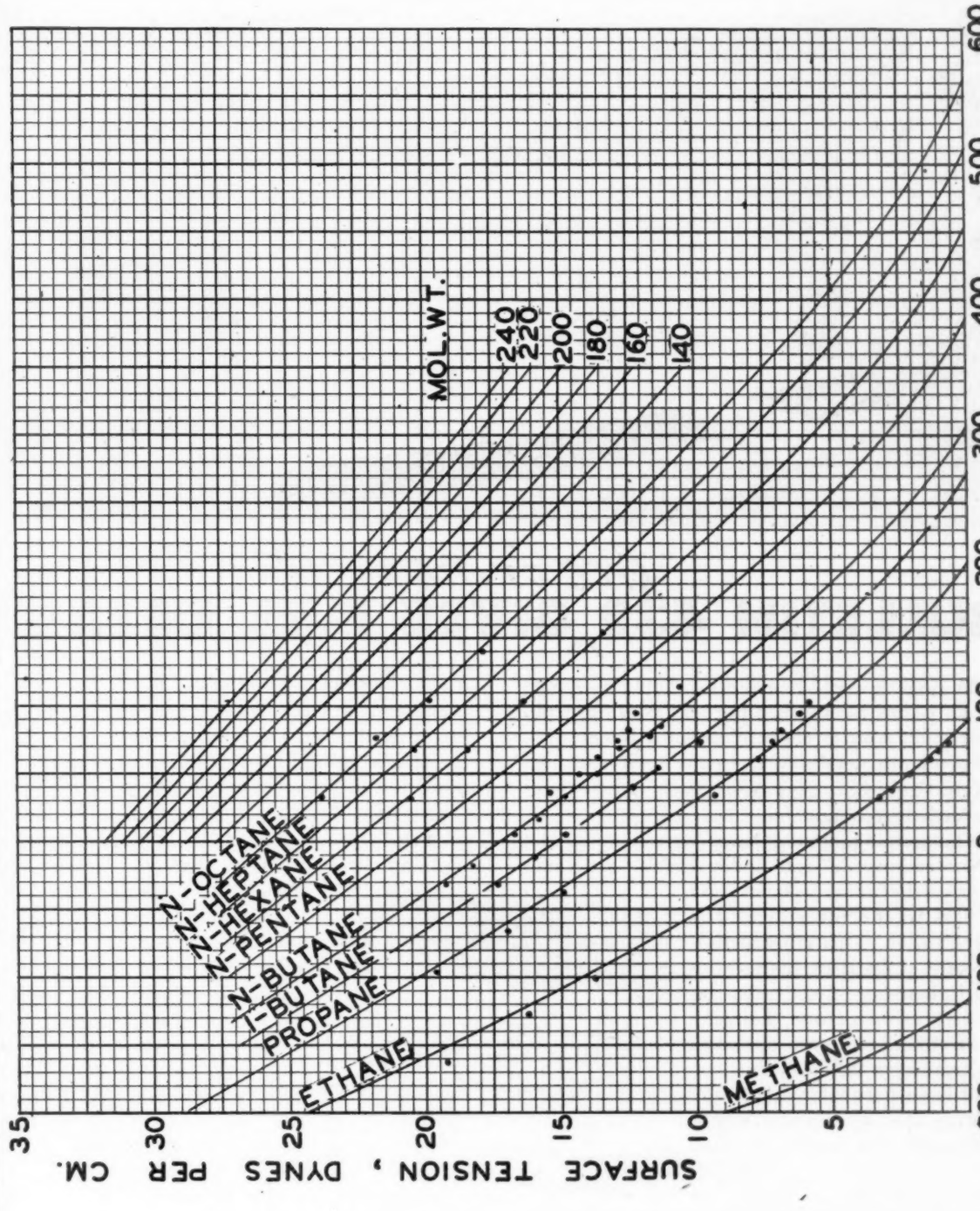
When ordering new equipment specify COOK'S Metallic Packings. For equipment in service, write us direct or our nearest office.

C. LEE COOK MANUFACTURING CO., Incorporated, Louisville, Kentucky. Branch Offices and Representatives—Baltimore, Boston, Chicago, Cleveland, Houston, Los Angeles, Mobile, Montreal, New Orleans, New York, Portland, Ore., San Francisco, Seattle, Tulsa.

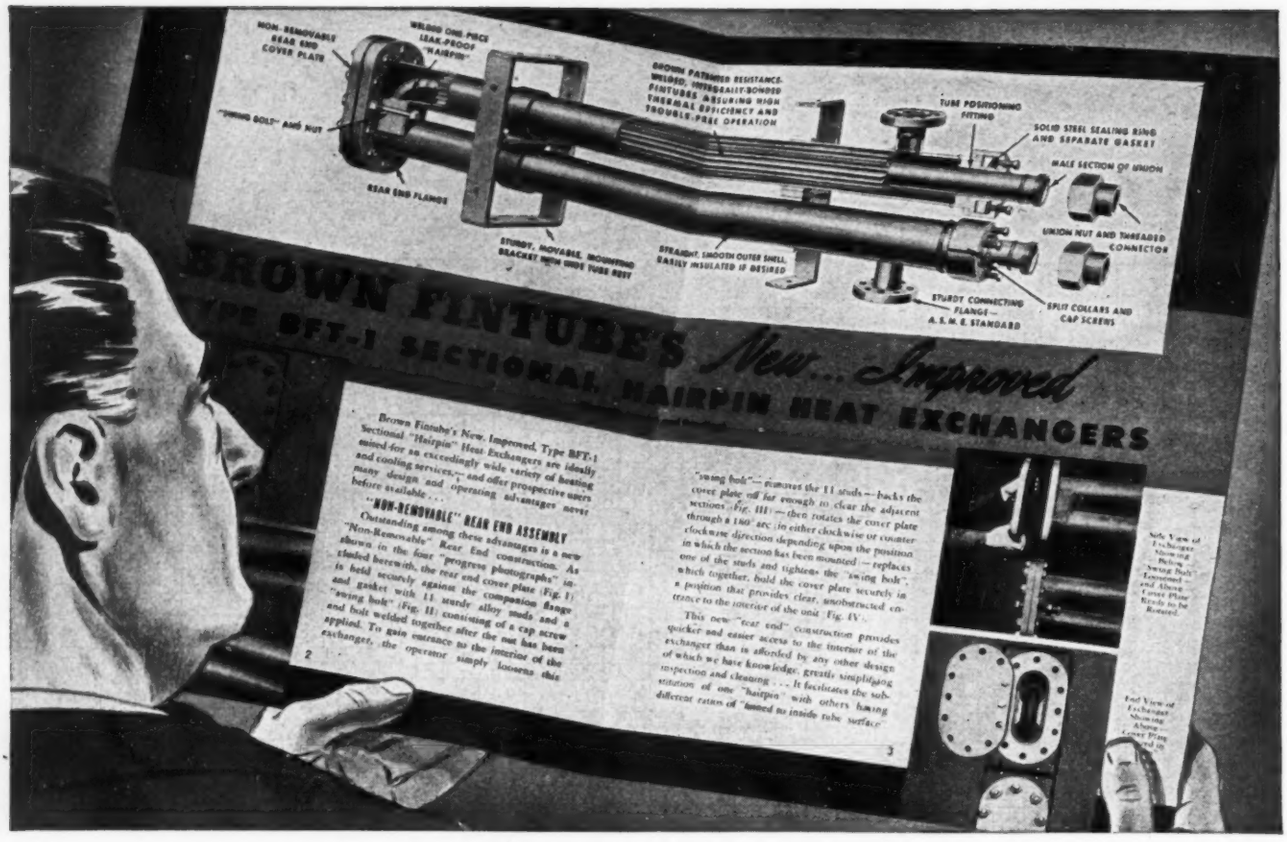
"Sealing Pressures Since 1888"

COOK'S METALLIC PACKINGS

SURFACE TENSION OF PARAFFIN HYDROCARBONS



—Chart by George Granger Brown, University of Michigan.



FREE ON REQUEST
BULLETIN 432 GIVES FULL DETAILS

• Engineers, works managers and operating men in all plants having heating and cooling problems, will want a copy of Bulletin No. 432... It gives full details of the new "sectional" heat exchangers that give users many advantages never before obtainable...

Outstanding among these new features is a "Non-removable" rear end assembly—see views above—that provides quick, easy access to the interior of the exchanger. This construction greatly simplifies inspection and cleaning—facilitates the substitution of one "hairpin" with others to secure optimum operation in different duties—and is of particular advantage when the exchangers are mounted high overhead, since it avoids the use of bell housings or other heavy members, and the work of removing these, lowering them to the ground, raising them back up, and putting them on again, for even the most routine inspection.

The new "head seal" is compact—holds the tube and shell in proper alignment—avoids any outboard stress or strain,—and can be assembled easily with a standard wrench.

Brown integrally-bonded Fintubes are used in all Brown Fintube Heat Exchangers,—are available in exchangers made by most other manufacturers,—and are ideally suited for many other heating and cooling services. Furnished in plain "longitudinal" or "cut and twisted" types,—wide range of sizes, in low carbon or special steels. Design assistance furnished gladly.

Other advantages are welded one-piece "hairpins",—the use of Brown resistance-welded, integrally-bonded Fintubes as the heat transfer medium—and —and— But get the *complete* story, together with dimensions of standard sizes, performance data, etc. It's all in Bulletin 432. Send for a copy today!

THE BROWN FINTUBE CO.

125 FILBERT STREET • ELYRIA, OHIO

MANUFACTURERS OF INTEGRALLY BONDED FINTUBES AND FINTUBE HEAT EXCHANGERS

CONSTANTS OF VAPORS AND GASES

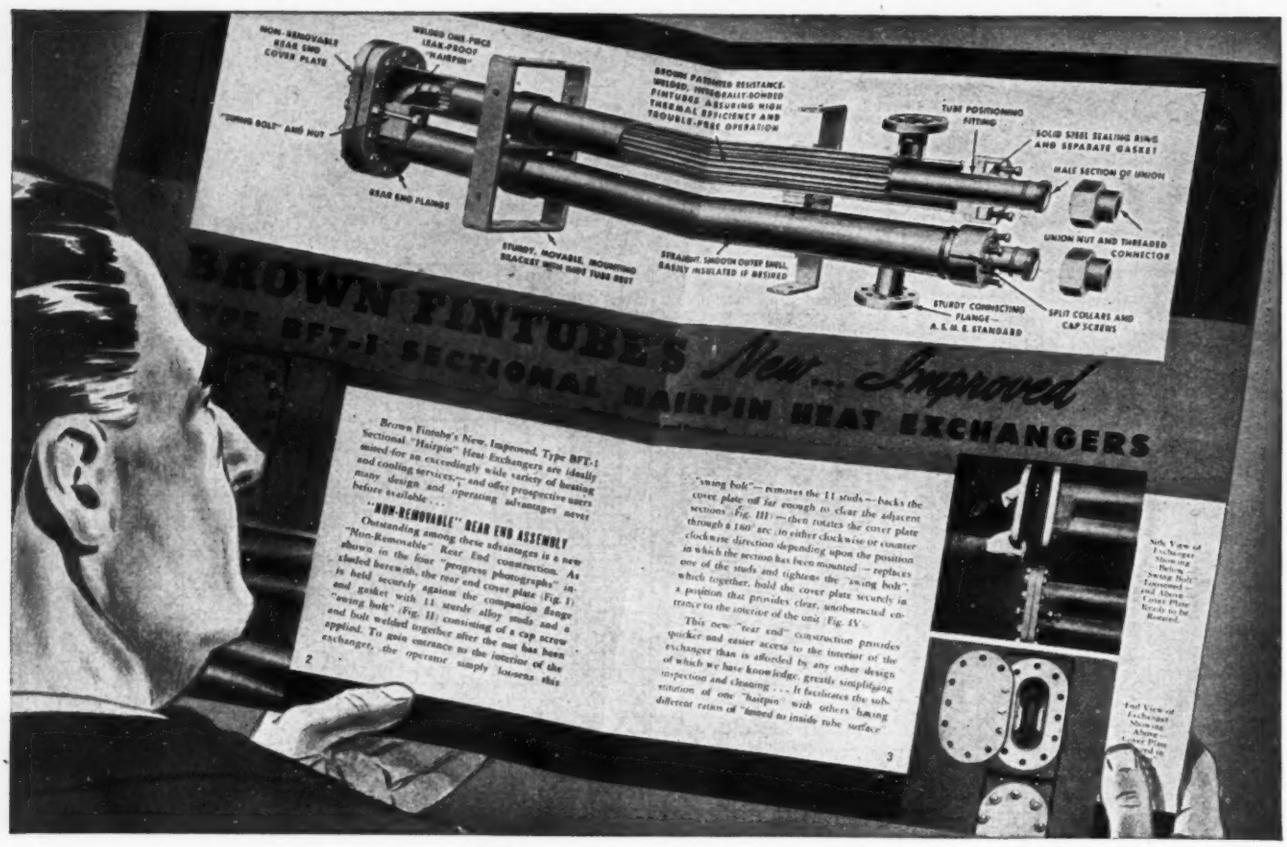
Gas	Atomic formula	Molecular weight (1939)	Sp. gr. at 29.92 in. Hg., and 60°F. Air=1	Density, lb. per cu. ft., 29.92 in. Hg. and 60°F.	Volume, cu. ft. per lb., 29.92 in. Hg., and 60°F.	Specific heat at constant pressure, 29.92 in. Hg., and 60°F./Cp	Specific heat at constant volume, 29.92 in. Hg., and 60°F./Cv	Cp/Cv at 29.92 in. Hg., and 60°F.	Boiling point at atmos. pressure, °F.	Critical temperature, °F.	Critical pressure, lb. per sq. in., abs.	Critical volume, cu. ft. per lb.
Acetylene	C_2H_2	26.0362	0.91	0.069	14.5	0.383	0.304	1.26–1.29	—118	97	911	0.0690
Air (dry)	.....	1.000	0.0764	13.100	0.2375	0.1689	1.406	—318	—221	547	0.0458
Ammonia	$N H_3$	17.0323	0.596	0.045	22.	0.52	0.39	1.31–1.32	—28	—270	1639	0.0682
Argon	A	39.944	1.379	0.105	9.49	0.123	0.74	1.66–1.67	—302.3	—187.6	705.4	0.0302
Benzene	C_6H_6	78.1086	.....	.....	.....	.....	.....	1.1–1.4*	176	551	701	0.0527
Butane (n)	C_4H_{10}	58.121	2.067	0.158	6.32	.....	.....	1.108–1.112	31	307	551	0.0691
Butene—1	C_4H_8	56.1048	1.93	0.148	6.76	...	...	....	23	...	...	...
Butene—2	C_4H_8	56.1048	2.00	0.153	6.56	...	...	....	34	...	...	...
Carbon dioxide	CO_2	44.010	1.53	0.117	8.55	0.203	0.156	1.30	—109	88	1073	0.0348
Carbon disulphide	CS_2	76.13	...	...	...	...	...	1.2*?	115	523.4	1117	0.0363
Carbon monoxide	CO	28.010	0.967	0.074	13.5	0.24	0.17	1.40–1.404	—314	—218	515	0.0515
Carbon tetrachloride	CCl_4	153.838	...	...	...	...	...	1.13–1.18*	170.2	541.7	661	0.0287
Chlorine	Cl_2	70.914	2.486	0.190	5.27	0.116	0.086	1.32–1.35	— 30.3	291.2	1118	0.0280
Dichlorodifluoromethane (F-12)	CCl_2F_2	120.924	4.25	0.325	3.07	...	...	1.138?	— 21.7	232.7	582.0	0.0289
Dichloromonofluromethane (F-21)	$CHCl_2F$	102.9321	...	0.284	3.52	...	...	1.12?	48.0	353.3	744.0	...
Dichloretetrafluoroethane (F-114)	$C_2Cl_2F_4$	170.934	...	0.465	2.20	...	...	1.09?	38.4	294.3	474.0	...
Dichloromethane	CH_2Cl_2	84.9402	...	...	...	...	...	1.18–1.224*	104	421	1490	...
Ethane	C_2H_6	30.0686	105	0.08	12.5	...	...	1.22	—127	90	717	0.0756
Ethyl Chloride	C_2H_5Cl	64.518	2.26	0.173	5.78	0.275	0.231	1.13–1.19	53.9	369.0	764.2	0.0485
Ethylene	C_2H_4	28.0524	0.975	0.0746	13.4	...	...	1.18–1.25	—155	50	748	0.0729
Helium	He	4.003	0.138	0.0105	94.9	1.25	0.75	1.66	—452.1	—450.2	33.2	0.2311
Hexane (n)	C_6H_{14}	86.1734	...	0.227*	4.4*	...	...	1.08–1.09*	156	455	434	0.0685
Heptane (n)	C_7H_{16}	100.1996	...	...	...	...	...	....	209	512.2	393.9	0.0685
Hydrogen	H_2	2.0162	0.0696	0.00532	187.85	3.41	2.42	1.41	—422.7	—400	188	0.5167
Hydrogen chloride	HCl	36.4651	1.268	0.097	10.33	0.193	0.137	1.39–1.41	—121.2	124.5	1199	0.0381
Hydrogen sulphide	H_2S	34.0762	1.19	0.091	11.0	0.25	0.19	1.32	— 75.2	217.7	1306	...
Isobutane	C_4H_{10}	58.121	2.067	0.158	6.32	...	...	1.11?	14	273	544	0.0685
Isobutene	C_4H_8	56.1048	1.99	0.152	6.58	...	...	....	20	290	...	...
Isopentane	C_5H_{12}	72.1472	...	0.19*	5.27*	...	...	1.097*	82	370	484	0.0686
Krypton	Kr	83.7	2.862	0.219	4.58	...	...	1.67–1.68	—241.2	—81.4?	793.6?	0.0205
Methane	CH_4	16.0424	0.554	0.0424	23.57	...	...	1.290–1.316	—259	—117	673	0.0989
Methyl chloride	CH_3Cl	50.4913	1.785	0.136	7.34	0.24	0.20	1.20–1.28	— 11.3	289.6	967	0.0433
Neon	Ne	20.183	0.696	0.0532	18.81	...	...	1.64	—410.7	—379.7	380.6	0.0331
Nitric oxide	NO	30.008	1.037	0.0792	12.63	0.232	0.166	1.394–1.41	—239.9	-137.2?	955.2?	0.0308?
Nitrogen (atm.)	N_2	28.016	0.9718	0.0744	13.44	0.247	0.176	1.404–1.41	—320.4	—232.8	492.3	0.515
Nitrous oxide	N_2O	44.016	1.529	0.1141	8.76	0.213	0.163	1.303–1.31	—129.1	97.7	1053.7	0.0355
Oxygen	O_2	32.000	1.1053	0.0846	11.82	0.217	0.155	1.398–1.401	—297.4	—182	731	0.0373
Pentane	C_5H_{12}	72.1472	...	0.19*	5.3*	...	...	1.086–1.097*	97	387	485	0.0688
Propane	C_3H_8	44.0948	1.56	0.119	8.36	...	...	1.16–1.136	— 44	206	617	0.0709
Propylene	C_3H_6	42.0786	1.45	0.11	9.0	...	...	1.146?	— 54	198	662	...
Sulphur dioxide	SO_2	64.06	2.264	0.1733	5.77	0.154	0.123	1.25–1.29	14.0	315.0	1142	0.0308
Trichloromonofluoromethane (F-11)	CCl_3F	137.381	...	0.388*	2.58*	...	...	1.135*?	74.67	388.4	636.0	...
Trichlorotrifluoroethane (F-113)	$C_2Cl_3F_3$	187.391	...	0.518*	1.93*	...	...	1.09*?	117.9	417.4	499.0	...
Water vapor	H_2O	18.0162	...	0.0374*	26.80*	0.48*	0.36*	1.27–1.33*	212.0	705.4	3206.2	0.0503
Xenon	Xe	131.3	4.525	0.3455	2.89	...	...	1.66–1.67	—164.4	61.9	855.3	0.0139

*At boiling point.

**A range of value is given for C_p/C_v where values of various authorities differ. A question mark indicates that insufficient independent sources of information are available.

Based on data from M. W. Kellogg Company, Kinetic Chemicals, Inc., International Critical Tables, U. S. Bureau of Standards Scientific Paper, No. 541, and Keenan and Keys.

Table from Compressed Air Data


BROWN FINTUBES New... Improved
BFT-1 SECTIONAL HAIRPIN HEAT EXCHANGERS
NON-REMOVABLE REAR END COVER PLATE
WELDED ONE-PIECE LEAK-PROOF "HAIRPIN"
"SWING BOLT" AND NUT
REAR END FLANGE
BROWN PATENTED RESISTANCE-WELDED, INTEGRALLY-BONDED FINTUBES ASSURING HIGH THERMAL EFFICIENCY AND TROUBLE-FREE OPERATION
TUBE POSITIONING FITTING
SOLID STEEL SEALING RING AND SEPARATE GASKET
MALE SECTION OF UNION
UNION NUT AND THREADED CONNECTOR
STURDY, MOVABLE, MOUNTING BRACKET WITH SLIDE TUBE REST
STRAIGHT, SMOOTH OUTER SHELL, EASILY INSULATED IF DESIRED
STURDY CONNECTING FLANGE— A. S. M. E. STANDARD
SPLIT COLLARS AND CAP SCREWS

free on request

BULLETIN 432 GIVES FULL DETAILS

• Engineers, works managers and operating men in all plants having heating and cooling problems, will want a copy of Bulletin No. 432... It gives full details of the new "sectional" heat exchangers that give users many advantages never before obtainable...

Outstanding among these new features is a "Non-removable" rear end assembly—see views above—that provides quick, easy access to the interior of the exchanger. This construction greatly simplifies inspection and cleaning—facilitates the substitution of one "hairpin" with others to secure optimum operation in different duties—and is of particular advantage when the exchangers are mounted high overhead, since it avoids the use of bell housings or other heavy members, and the work of removing these, lowering them to the ground, raising them back up, and putting them on again, for even the most routine inspection.

The new "head seal" is compact—holds the tube and shell in proper alignment—avoids any outboard stress or strain,—and can be assembled easily with a standard wrench.

Brown integrally-bonded Fintubes are used in all Brown Fintube Heat Exchangers,—are available in exchangers made by most other manufacturers,—and are ideally suited for many other heating and cooling services. Furnished in plain "longitudinal" or "cut and twisted" types,—wide range of sizes, in low carbon or special steels. Design assistance furnished gladly.

Other advantages are welded one-piece "hairpins",—the use of Brown resistance-welded, integrally-bonded Fintubes as the heat transfer medium—and —and— But get the *complete* story, together with dimensions of standard sizes, performance data, etc. It's all in Bulletin 432. Send for a copy today!

THE BROWN FINTUBE CO.

125 FILBERT STREET • ELYRIA, OHIO

MANUFACTURERS OF INTEGRALLY BONDED FINTUBES AND FINTUBE HEAT EXCHANGERS

CONSTANTS OF VAPORS AND GASES

Gas	Atomic formula	Molecular weight (1939)	Sp. gr. at 29.92 in. Hg., and 60°F. Air=1	Density, lb. per cu. ft., 29.92 in. Hg. and 60°F.	Volume, cu. ft. per lb., 29.92 in. Hg., and 60°F.	Specific heat at constant pressure, 29.92 in. Hg., and 60°F./Cp	Specific heat at constant volume, 29.92 in. Hg., and 60°F./Cv	Cp/Cv at 29.92 in. Hg., and 60°F.	Boiling point at atmos. pressure, °F.	Critical temperature, °F.	Critical pressure, lb. per sq. in., abs.	Critical volume, cu. ft. per lb.
Acetylene	C_2H_2	26.0362	0.91	0.069	14.5	0.383	0.304	1.26–1.29	—118	97	911	0.0690
Air (dry)	.....	.....	1.000	0.0764	13.100	0.2375	0.1689	1.406	—318	—221	547	0.0458
Ammonia	N H_3	17.0323	0.596	0.045	22.	0.52	0.39	1.31–1.32	—28	—270	1639	0.0682
Argon	A	39.944	1.379	0.105	9.49	0.123	0.74	1.66–1.67	—302.3	—187.6	705.4	0.0302
Benzene	C_6H_6	78.1086	.....	.....	.....	.....	.....	1.1–1.4*	176	551	701	0.0527
Butane (n)	C_4H_{10}	58.121	2.067	0.158	6.32	.....	.....	1.108–1.112	31	307	551	0.0691
Butene—1	C_4H_8	56.1048	1.93	0.148	6.76	...	...	....	23	...	...	...
Butene—2	C_4H_8	56.1048	2.00	0.153	6.56	...	...	....	34	...	...	...
Carbon dioxide	CO_2	44.010	1.53	0.117	8.55	0.203	0.156	1.30	—109	88	1073	0.0348
Carbon disulphide	CS_2	76.13	...	...	...	...	...	1.2*?	115	523.4	1117	0.0363
Carbon monoxide	CO	28.010	0.967	0.074	13.5	0.24	0.17	1.40–1.404	—314	—218	515	0.0515
Carbon tetrachloride	CCl_4	153.838	...	...	...	...	...	1.13–1.18*	170.2	541.7	661	0.0287
Chlorine	Cl_2	70.914	2.486	0.190	5.27	0.116	0.086	1.32–1.35	— 30.3	291.2	1118	0.0280
Dichlorodifluoromethane (F-12)	CCl_2F_2	120.924	4.25	0.325	3.07	...	...	1.138?	— 21.7	232.7	582.0	0.0289
Dichloromonofluromethane (F-21)	$CHCl_2F$	102.9321	...	0.284	3.52	...	...	1.12?	48.0	353.3	744.0	...
Dichloretetrafluoroethane (F-114)	$C_2Cl_2F_4$	170.934	...	0.465	2.20	...	...	1.09?	38.4	294.3	474.0	...
Dichloromethane	CH_2Cl_2	84.9402	...	...	...	...	...	1.18–1.224*	104	421	1490	...
Ethane	C_2H_6	30.0686	105	0.08	12.5	...	...	1.22	—127	90	717	0.0756
Ethyl Chloride	C_2H_5Cl	64.518	2.26	0.173	5.78	0.275	0.231	1.13–1.19	53.9	369.0	764.2	0.0485
Ethylene	C_2H_4	28.0524	0.975	0.0746	13.4	...	...	1.18–1.25	—155	50	748	0.0729
Helium	He	4.003	0.138	0.0105	94.9	1.25	0.75	1.66	—452.1	—450.2	33.2	0.2311
Hexane (n)	C_6H_{14}	86.1734	...	0.227*	4.4*	...	...	1.08–1.09*	156	455	434	0.0685
Heptane (n)	C_7H_{16}	100.1996	...	...	...	...	...	....	209	512.2	393.9	0.0685
Hydrogen	H_2	2.0162	0.0696	0.00532	187.85	3.41	2.42	1.41	—422.7	—400	188	0.5167
Hydrogen chloride	HCl	36.4651	1.268	0.097	10.33	0.193	0.137	1.39–1.41	—121.2	124.5	1199	0.0381
Hydrogen sulphide	H_2S	34.0762	1.19	0.091	11.0	0.25	0.19	1.32	— 75.2	217.7	1306	...
Isobutane	C_4H_{10}	58.121	2.067	0.158	6.32	...	...	1.11?	14	273	544	0.0685
Isobutene	C_4H_8	56.1048	1.99	0.152	6.58	...	...	....	20	290	...	...
Isopentane	C_5H_{12}	72.1472	...	0.19*	5.27*	...	...	1.097*	82	370	484	0.0686
Krypton	Kr	83.7	2.862	0.219	4.58	...	...	1.67–1.68	—241.2	—81.4?	793.6?	0.0205
Methane	CH_4	16.0424	0.554	0.0424	23.57	...	...	1.290–1.316	—259	—117	673	0.0989
Methyl chloride	CH_3Cl	50.4913	1.785	0.136	7.34	0.24	0.20	1.20–1.28	— 11.3	289.6	967	0.0433
Neon	Ne	20.183	0.696	0.0532	18.81	...	...	1.64	—410.7	—379.7	380.6	0.0331
Nitric oxide	NO	30.008	1.037	0.0792	12.63	0.232	0.166	1.394–1.41	—239.9	—137.2?	955.2?	0.0308?
Nitrogen (atm.)	N_2	28.016	0.9718	0.0744	13.44	0.247	0.176	1.404–1.41	—320.4	—232.8	492.3	0.515
Nitrous oxide	N_2O	44.016	1.529	0.1141	8.76	0.213	0.163	1.303–1.31	—129.1	97.7	1053.7	0.0355
Oxygen	O_2	32.000	1.1053	0.0846	11.82	0.217	0.155	1.398–1.401	—297.4	—182	731	0.0373
Pentane	C_5H_{12}	72.1472	...	0.19*	5.3*	...	...	1.086–1.097*	97	387	485	0.0688
Propane	C_3H_8	44.0948	1.56	0.119	8.36	...	...	1.16–1.136	— 44	206	617	0.0709
Propylene	C_3H_6	42.0786	1.45	0.11	9.0	...	...	1.146?	— 54	198	662	...
Sulphur dioxide	SO_2	64.06	2.264	0.1733	5.77	0.154	0.123	1.25–1.29	14.0	315.0	1142	0.0308
Trichloromonofluoromethane (F-11)	CCl_3F	137.381	...	0.388*	2.58*	...	...	1.135*?	74.67	388.4	636.0	...
Trichlorotrifluoroethane (F-113)	$C_2Cl_3F_3$	187.391	...	0.518*	1.93*	...	...	1.09*?	117.9	417.4	499.0	...
Water vapor	H_2O	18.0162	...	0.0374*	26.80*	0.48*	0.36*	1.27–1.33*	212.0	705.4	3206.2	0.0503
Xenon	Xe	131.3	4.525	0.3455	2.89	...	...	1.66–1.67	—164.4	61.9	855.3	0.0139

*At boiling point.

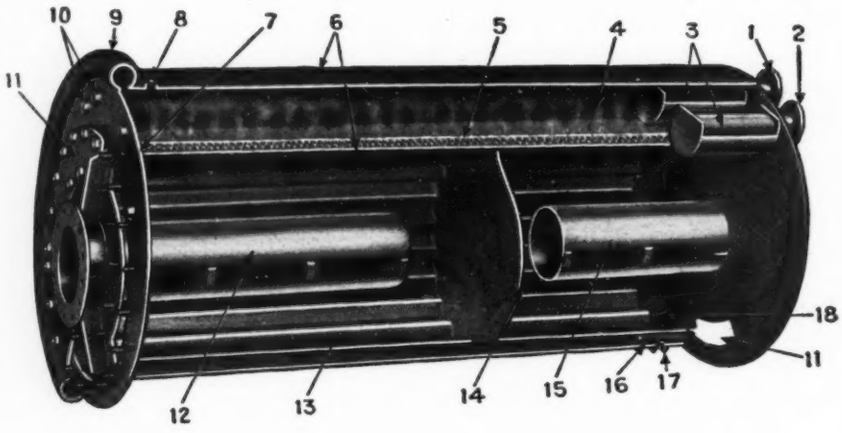
**A range of value is given for C_p/C_v where values of various authorities differ. A question mark indicates that insufficient independent sources of information are available.

Based on data from M. W. Kellogg Company, Kinetic Chemicals, Inc., International Critical Tables, U. S. Bureau of Standards Scientific Paper, No. 541, and Keenan and Keys.

Table from Compressed Air Data

MAXIM HEAT RECOVERY SILENCERS *save fuel!*

Extra steam or hot water for industrial processing operations or for heating purposes can be readily obtained by utilizing waste exhaust heat with Maxim Heat Recovery Silencers. The fuel saving is obvious, as the heat source is simply the engine exhaust gases which normally are wasted.



1—Steam Outlet
2—Safety Valve Connection
3—Dry Pipes
4—Steam Space
5—Water Line
6—Shells—Cylindrical to withstand steam pressure and pulsating gas flow
7—Inlet Head
8—Pressure Gauge Connection
9—Expansion Joint—permits dry operation
10—Water Gauge Connections
11—Cleanouts—provide easy access for cleaning heating surface
12—Inlet Bleeder Tube
13—Extended Heating Surface—forming conduits for leading exhaust gases from one attenuating chamber to the other
14—Insulated Intermediate Head
15—Outlet Bleeder Tube
16—Feed Water Deflector Plate
17—Feed Water Connection
18—Exhaust Gas Outlet from side conduits formed by extended heating surfaces

HIGH HEAT RECOVERY ... Maxim Heat Recovery Silencers achieve highly efficient heat transfer through high mass gas velocities and the use of extended heating surfaces, a type of construction that is extremely dependable and requires minimum attention.

HIGH DEGREE OF SILENCING ... These units embody the Maxim principle of silencing and can be had with or without the spark arresting feature. Based on silencing principles pioneered by Maxim and developed through years of practical field experience, they afford highly effective silencing of exhaust with minimum of back pressure.

COMPACTNESS AND LIGHT WEIGHT ... Maxim Heat Recovery Silencers are extremely compact and can in most cases be installed in the space normally used for a regular silencer unit.

AUTOMATIC CONTROL ... In the boiler, the steaming rate is controlled by varying the amount of water in contact with the heating surface; low water, less effective heating surface; high level, more effective. The control is accomplished automatically by two steam pressure regulated valves, one in the feed line, one in the return line, working in conjunction. (See bulletin WH-100)

ABILITY TO RUN DRY ... Because of the type of construction, with extended heating surfaces, not tubes, it is possible to run these units dry without any danger of damage.

QUICK RETURN ON INVESTMENT ... Maxim Heat Recovery Silencers produce usable steam or hot water from a present source of heat. Hence steam or hot water for processing operations or for heating the plant is available with no extra fuel cost. This obvious saving represents a quick and often substantial return on your investment

AVAILABILITY ... At this time the Maxim Silencer Company's production is devoted to war needs. It is our feeling, however, that this Waste Heat story has sufficient post-war importance to make your investigation worthwhile now, whether or not your present priority status allows immediate purchase of the equipment.

This northern Minnesota power plant is heated entirely through use of Maxim Heat Recovery Silencers.

SEND FOR DESCRIPTIVE BULLETINS

Maxim Waste Heat Bulletins WH-100, WH-102 and WH-103 will be sent to you on request. Simply send your request to The Maxim Silencer Company at the address below.

THE MAXIM SILENCER CO.
90 Homestead Ave., Hartford, Conn.

MAXIM

POLISHED ROD LOADS

Rod size, in.	Rod area, sq. in.	Rod wt., 100 ft.	Wt. water per 1000 ft. sp. gr. 1.0	Pump diameter, in.										
				1	1 1/16	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3 3/4	4 3/4
				Dead weight of rods and fluid										
5/8	0.307	1130		207	251	398	632	911	1230	1590	1990	2440	4650	7540
3/4	0.442	1630		149	193	340	574	852	1170	1530	1930	2380	4590	7480
7/8	0.601	2190		80	124	271	505	783	1100	1460	1870	2310	4520	7410
1	0.785	2880		0	44	191	425	704	1020	1380	1790	2230	4440	7330
Bbl. daily per 10-in. stroke per 10 s.p.m. at 100 percent efficiency				11.6	13.2	18.2	26.3	35.7	46.6	59.0	72.9	88.2	164	263
Hp. per 10-in. stroke per 10 s.p.m. per 1000 ft. at 100 percent efficiency				0.086	0.097	0.134	0.193	0.264	0.343	0.435	0.573	0.650	1.21	1.94

Use 75 per cent volumetric efficiency for average pump condition. Use 65 per cent power efficiency for average pump condition.

Example: 5000 ft. depth, 1¾-in. pump barrel, 1500 ft. ⅞-in. and 3500 ft. ¾-in., 30° A.P.I. oil, 53-in. stroke, and 20 s.p.m.

Solution: Wt. rods $=1.500\times2190+3.500\times1630=9000$ lb.

Wt. fluid $=0.876\ (1.500\times783+3.500\times852)=3641$ lb.

Total dead load $=12{,}641$ lb.

Impulse factor from Mills' formula: $\text{I.F.}=1+\dfrac{\text{stroke}\times(\text{s.p.m.})^2}{70{,}500}$ $\qquad$ $\text{I.F.}=1+\dfrac{53\text{ in.}\times(20)^2}{70{,}500}=1.3$

Peak Load $=12{,}641\times1.3=16{,}420$ lb.

Production at 75 per cent volumetric efficiency $=35.7\times5.3\times2.0\times0.75=283$ bbl. per day.

Horsepower at 65 per cent power efficiency $=0.264\times5.3\times2.0\times5.000\times\dfrac{1}{0.65}=21.0$ hp.

Table by A. S. Ross, The Texas Company

There's still a big job for all of us to do

NOTHING MATTERS NOW except the swift and certain winning of the war.

Through the prodigious production accomplishments of American industry, our men and our Allies have been able to swing the initiative in fighting to our side.

To keep it...to continue a steady march on the bloody road to victory... we've got to give our men in the thick of the fight everything they'll need. And give it to them faster and faster!

For you and for us there's *still* a big job to be done. The history of the amazing production performance of American industry is *still* to be written.

Every single man-hour, every bit of brain power, every ounce of industrial energy expended for any purpose other than victory will damage the war effort.

The entire production of Hyatt Roller Bearings now goes into planes our men fly... into tanks they drive... into ships they sail... into guns they man... into equipment they need to win.

In the midst of pouring out a tremendous stream of bearings for this vital war use, we pause to again thank industry for its grand cooperation and understanding, and for helping us meet war's demands for super-precision production on a mass scale.

As soon as the war's won, and this job is done, Industry and Hyatt will have another big job to do together... when we can work in Peace.

Hyatt Bearings Division, General Motors Corporation, Harrison, N. J.

DIVISION OF

HYATT BEARINGS GENERAL MOTORS

What It Costs to Drill

PETROLEUM ENGINEER Exclusive Feature

☆ Complete records provide basis for determining cost of drilling future wells

by W. K. Powell

Two States Drilling Company

THE AUTHOR

was graduated with B.S. in marketing from from Southern Methodist University, 1928—Later made additional studies of accounting and petroleum geology—After 1928, worked a year adjusting fire insurance claims—From 1929 through 1933, engaged in cotton export trade—Pursuing an interest in petroleum geology, the years of 1933 and 1934 were spent as an oil scout and land man on special assignments—Collaborating at intervals over this period with the public accounting firm of Hutchinson, Bonner and Burleson, interest was centered on accounting and its problem with the oil industry—Recommended by that firm to the Two States Drilling Company as an accountant in 1935—Has advanced into the general management organization of the company—Also, is an officer of the Two States Oil Company, of the Service Supply Company, the Dixie Pipe and Equipment Company, Henry Lane Service, Inc., and is actively interested in the Technilube Company—At present is chairman of Accounting Practices Committee of the American Association of Oilwell Drilling Contractors—Resides in Dallas, Texas.

GULLIBLE gusher gatherers have been suffering for years from acute indigestion as a result of swallowing whole the many loose answers to the oil country's most pursued question: "What will it cost to drill?" These speculative answers have been as far apart as the crown block from the drill collar and as devoid of foundation as Paul Bunyan's derrick after the windstorm. The mass have been highly optimistic regarding drilling costs. In fact, there has been a cheerful legion that based a sincere belief in the low cost of drilling on "Jim says" backed by a hot desire to get the well spudded. Encouraging to those who look upon oil as an industry is the fact that this illusion is steadily diminishing. As the industry has grown and the extractive profit processes have become more difficult, those figures representing well costs have been regarded more critically. The trend has been to improve greatly cost records for the dual purpose of analyzing specific work for correction or improvement and for the purpose of better estimating the cost of new work.

Present-day practice is not the ultimate but it does represent an advanced stage of good cost accounting. Operators and contractors who are drilling today's wells speak with far more authority on the subject of well costs than ever before. To explore this ability an exposition of the methods of one recommended type of well cost accounting is selected in the belief that explicit details may be more illuminating and helpfully suggestive than generalization on the subject. Therefore, this study will confine itself to the various records of well cost that are auxiliary to the general records. The well ledger will be given prime consideration as befits its basic position.

The Well Ledger

The well ledger is primarially a sub ledger in accounting parlance. That is, it is an additional book used in connection with the general ledger to give detailed information supporting the grosser figures of the general ledger. The total of the components in the well ledger will balance with the general ledger control accounts. In the general ledger are recorded bulk figures for the costs of wells and in the well ledger these same figures of expense are broken down into all useful details. Although the well ledger may be used with any existing set of books, it combines most effectively with the voucher system, a system under which no delay is necessary in distributing and recording expense. This combination also permits complete and ready access to the original supporting data as all original supporting data are attached permanently to the voucher copy and the voucher copy is filed numerically in appropriate files. Reference is made to the voucher by the entry of the voucher number in the space provided for that purpose on each line of the well ledger sheets.

In the well ledger are set up expense accounts for each well as it is drilled. These separate expense accounts should provide identifying information in their headings giving the well designation, county, state and field location, the rig used, and should include an index. The size of the sheet used is a matter of individual preference; however, a double page, 43 column, 36 line sheet with item space on the left, measuring 11 in. by 19 in. to the single sheet has proved to be very convenient. Only the first two left-hand columns are double, providing for both a debit and credit column. All other columns are single debit columns, for in order to conserve space, the few credits that will be encountered are entered in the debit columns in red. Of course the number of columns will depend entirely upon the "breakdown" or detail of the expense. As has been suggested above, the amassing of detail is costly and should only be done to serve a real need. All expenses can be allocated into significant classes without going into such detail as to be absurd. For instance, the knowledge gained from the total of "oil and greases" is sufficient, as it will be the indicator that suggests investigation as it varies from the norm. No more could be gained from extreme details such as the recording of the cost of each class and weight of oil and grease in use unless repair expenses or other costs indicate a detailed study of lubricants should be made. In this case an additional and probably temporary accounting would be made to solve the trouble. The "break-down" of expense should be treated as the selection of gauges and measures of operation. The divisions should be practical from the standpoint of both office and field. Furthermore, selection of the expense groups should conform as much as possible to the conventional method in which purchases and services are invoiced. The order of appearance of the items of expense will be improved by grouping naturally related items such as "superintendence

expense," "labor," "compensation and liability insurance," "fire, boiler and other insurance," etc. For the convenience of reports to be derived from the well expense, it is handy to have the sequence such that all items of a straight drilling contract precede those items such as "fuel," "water," "derrick," "cement," "cementing services," "casing," "tubing," etc., which create contractual variations shading into a complete turnkey contract. Or in the case of an operator drilling his own production the intangible items might take precedence over the tangible to facilitate later division as dictated by tax policy.

In practice usually a number of invoices are handled on one voucher and the distributions of those invoices are pooled. For example, assuming that the Blank Supply Company invoices at tached to a voucher for $1,323.01, are inspected and it is found that a number of the same expense class items appear on various invoices. A work sheet would be prepared on which all cost items of the same class would be consolidated. Under "bits and reamer" would appear Inv. 10342 for $85.00, Inv. 11162 for $170.00, and Inv. 11293 for $163.50, totaling $333.50 for which the entry on the voucher face would be "bits and reamers" — Gulf-Smith No. 3 — $333.50 or the total entry on the voucher might appear as follows:

	Dr.	Cr.
Gulf-Smith No. 3—		
Bits and reamers	$333.50	
Machinery, parts	162.17	
Miscellaneous supplies	31.82	
	$527.49	
Ohio-Barksdale No. 1—		
Bits and reamers	$633.50	
Rotary chain	158.50	
	$792.00	
Amerada-Peach No. 3—		
Miscellaneous supplies	$ 3.52	
Vouchers payable—		
Blank Supply Company		$1,323.01

Obviously once this distribution is made, it may be entered or "posted" on the proper sheets of the well ledger by any careful and dependable clerk. This and the fact that the well ledger may be sub-divided into as many books as desirable mean that this type of cost accounting is not only highly flexible but that many of its functions can be performed by less experienced help. There is no substitute for experienced and competent personnel in the making of expense distributions, however.

Correctness in allocating expense and consistency in the classifying of expense items are of utmost importance in the operation of an effective cost record. On these points most failures of effectiveness are founded. The accountant who handles expense distributions must not only be proficient in his profession but must know a great deal about the oil business and considerable about the particular operations for which he is accounting. Few realize the tremendous value of a close relationship between the field and office in this connection. The person who handles the distribution of expense should have a working knowledge of the field operations and the first hand information possessed by that person should be kept current through frequent personal observations of operations. Only in this manner will the accountant be able to solve the many riddles that he encounters in the heterogeneous charges received. In this manner he will be able to anticipate needs. He will talk with his field personnel and learn what to diagnose, what the field needs to know, what the field ought to know, what is feasible, and what is not. All valuable information the field organization can supply should be extracted in the easiest possible manner, digested, and fed back to operations in a simple, understandable form. The chief function of the well ledger is to supply the material for the guidance of operations so that the greatest advantage may be procured from those practices revealed to be the most efficient.

Items of Indirect Expense

Direct expense or actual cash outlay as accounted for in the well ledger is usually readily understandable by all concerned. There is a running mate called indirect expense that is less well known and that sometimes takes on the form of a bugaboo. Indirect expense is all expense that an organization incurs in running its business that is not immediately charged to a particular operation and which expense must be borne by the gross earnings of the operations. Overhead expense, depreciation, and depletion are indirect expenses. There is nothing mysterious about overhead. It is composed of the prosaic things like officers salaries, office wages, rent, interest, general insurance, taxes, telephone and telegraph, traveling expense, etc.

Depreciations

Depreciation is just a short way of identifying the allocating of the cost of capital goods over the period of its life expectancy. A mortality table for the equipment used to drill wells is created on the basis of past experience. For simple depreciation the cost of an item is divided by its estimated life and the resulting figure is the amount charged off each year as depreciation expense with the charge off repeating itself each year until all the cost has been written off and recorded in the depreciation reserve. Obsolescence and use factors sometimes make this "straight line" depreciation method less practical and consequently there are many variations. Among the best methods in use for drilling equipment are those that use time of operation as the basis for the allocation of depreciation expense. This method assumes that the equipment will be in use frequently enough to obviate obsolescence. An estimate is made of how long a rig will run continuously without having to be replaced and from this estimate is derived a factor of depreciation expense for each hour the drilling equipment is in operation. For instance, 3 years has been assumed to be the life of a drilling rig and on this basis the cost of the rig is divided by 1095 to determine the depreciation expense incurred in one day's operation. Incidentally, this figure has been carefully checked against actual conditions and found to be very close. In actual practice the entire amount of depreciation is not realized for from 6 to 8 years because in no known case has an operation been found that was continuous. The use of this method against actual active hours of rig operation or by assuming the crew days on a drilling operation as the active time results in such a small variation that the latter is the more desirable. Using the depreciation factor, which will range from $50 to $100 per crew day for medium to medium large rotary drilling rigs, against the crew days for a given well will enable anyone to calculate rapidly the depreciation expense of a well or to estimate quickly the indirect costs of prospective work. Overhead expense may be reduced to a factor that is usable in much the same manner by using a prior year's overhead divided by total active working hours or days for that year. Caution should be taken to adjust such a figure with each succeeding year although appreciable fluctuations will be exceptional.

Drill Pipe Depreciation

Drill pipe may be handled in a manner similar to that of drilling equipment, but there is one variation that is interesting because it again provides a readily usable factor in calculating the cost of a well. This method requires a drill pipe usage history of several years to acquire a workable average. The cost of the drill pipe used over a given period less the residual value of pipe on hand at the end of the test period is divided by the total footage of hole drilled within the period. This is done for each size of pipe until factors are established for each size in use. Pipe used in the same general area should comprise the record for the factor in each general area. As an example, it has been found on the study of an 8-year period that within a few decimal points the following factors reflect quite accurately the depreciation ex-

Baash-Ross News

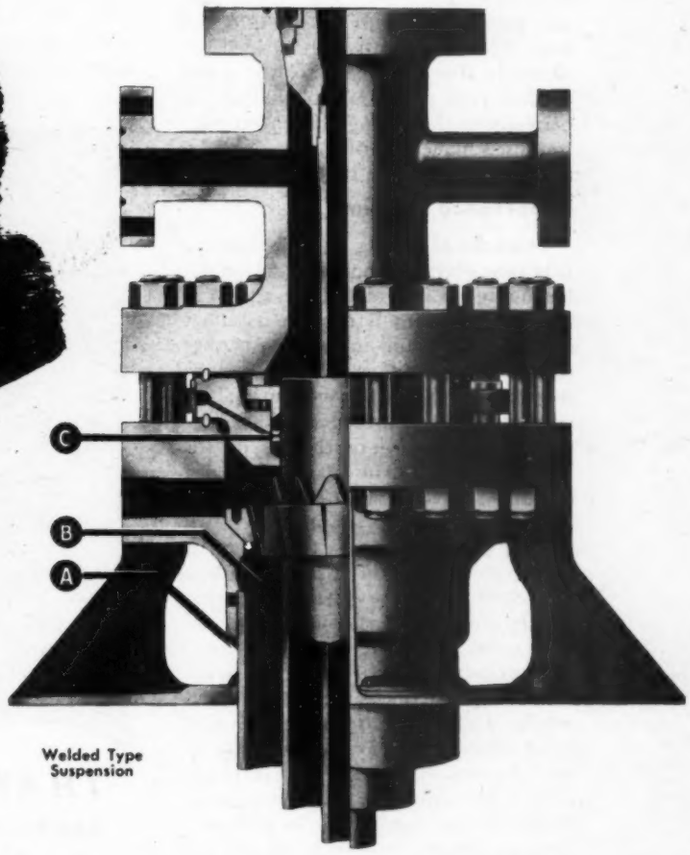
BAASH-ROSS TOOL COMPANY · LOS ANGELES · HOUSTON · NEW YORK

PETROLEUM ENGINEER EDITION

Here's important news in the new BAASH-ROSS casing head

New

...to pioneer the modern all-welded casing ..., has now perfected another major advancement in casing ...pension technique—the new Baash-Ross Casing and Landing Heads. These new ...h-Ross Heads are packed with important developments—advanced features ...h assure a better pack-off, a stronger suspension and easier maintenance ...ughout the life of the well . . .



Welded Type Suspension

...TURE 1. DOUBLE SEAL AGAINST LEAKS: In the new Baash-Ross Head the casing is ...ed to the head with *two* full circumferential welds. These two welds (A and B) ...e a *double* seal against leaks—*double* protection against high casing pressures ...er all types of conditions.

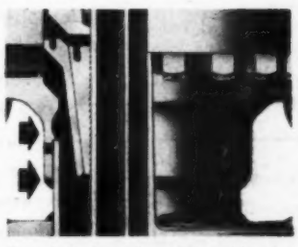
...TURE 2. STRONGER CASING SUPPORT: To insure the best possible weld at each ...nt, the support flange has been specially engineered with a wall section approxi...ely equal to that of the casing. This insures uniform heat distribution between ...g and flange when welding and prevents risk of too rapid heat flow which would ...t if a heavy mass of metal were opposite the weld. Thus, the casing is not only ...ported by *two* welds instead of one, but each weld is more uniform, stronger!

...TURE 3. POSITIVE PRESSURE-CHECK: The double welds are not only stronger and ...e leakproof, but they also provide means for pressure-testing both welds at once to ...re a complete positive seal at both points. Simply remove two plugs located on ...posite sides of the base, screw a gage into one opening and a pressure pump to the ...er. Then high pressures can be applied to the annular space between the welds and ...h welds simultaneously pressure-checked for leaks. It's quick and positive!

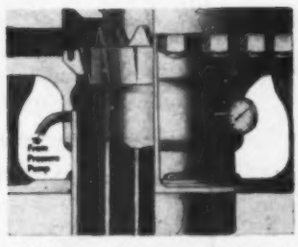
...TURE 4. PLASTIC PACK-OFF: Should a leak show up when the welds are tested, it ...n be quickly sealed off by pressure-pumping plastic packing into the annular space ...tween the welds. The packing completely fills the space between the welds, sealing off ...l leaks, small or large. The pack-off for succeeding casing strings (C) is designed ...th an annular space between packing rings that also can be pressure-tested and ...stic-packed to seal off any leaks. Thus, pack-off on ALL strings is simple, fool-...oof, *positive!*

...TURE 5. EASY MAINTENANCE: At any time throughout the life of the well *any* of ...e casing strings can be quickly re-tested for pack-off by simply removing the plugs, ...aching a gage and applying pressure. And if a leak is discovered, it can be quickly ...cked-off by simply pumping plastic packing into the space between welds or packing ...g, as the case may be.

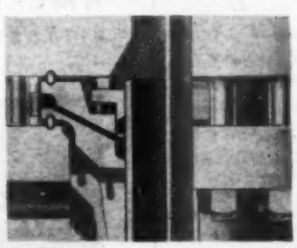
And this entire operation, from pressure-testing to pack-off, can be ...complished in the matter of a few minutes without dismantling the head . . . ...thout breaking connections . . . without welding (dangerous if gas is present!) ...and without killing the well!



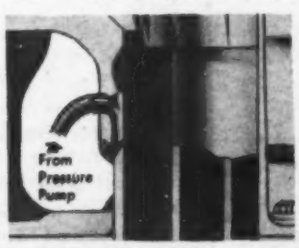
Two full circumferential welds give *double seal, double support.* Note thin-wall of base flange opposite welding points. This view shows slip type suspension of casing.



Welds can be pressure-checked simultaneously for leaks through threaded openings on opposite sides —one for gage, the other for connecting a hydraulic pressure pump.



Succeeding strings are sealed by double packing rings separated by open channel. Threaded connections to this channel permit pressure-checking, plastic-packing here, too.



Any leaks discovered can be readily sealed off by forcing plastic packing into space between welds or packing rings on any desired string without dismantling head or killing the well.

This new Baash-Ross development is available in both welded suspension and slip suspension heads for use with all standard API flanges, tubing heads and spools. See page 268 of the 1944 Composite Catalog for further details . . . or write direct for full information and recommendations to fit your *particular* casing program!

pense per day on drill pipe in West Texas:

2⅝ in.—1¼ cents per ft.
3½ in.—1½ cents per ft.
4½ in.—1¾ cents per ft.
6⅝ in.— 2 cents per ft.

Sufficient evidence has not yet been accumulated to determine the effect of the new "Victory" pipe on these factors. In applying these factors the maximum footage of pipe in the hole each day is used. For practical reasons tours are considered in place of hours with each tour representing one-third of a day and any part of a tour representing a full tour. These factors have been used extensively also as the basis for the rental of drill pipe at cost although they, in common with drilling equipment factors used likewise, fail to take into account any interest on the investment.

Importance of Time

From the foregoing it will be noticed that time plays an important role in determining the cost of drilling a well. In fact so important is time in its effect on both direct and indirect costs that no accounting for well costs can be complete without an accounting for time. Every well drilled should be analyzed with regard to the use of the hours on the job. This may or may not be tied in directly with the other records but taken in conjunction with them it will become most revealing. An application of all the expense to time may result in factors that are invaluable in calculating the cost of future work or in estimating the cost of completions before all charges have been received. An estimate becomes much simpler with only one unknown. Only in completely unexplored territory or at unexplored depths would there be much chance for damaging variations from the actual final result. Time or well performance records will help to allocate trouble spots in work and are extremely important in evaluating men and materials. Time records encompass many other special cost records such as bit records, which are common on every derrick floor. They should be used as need and reason dictates and should be freely discarded when no longer of value. Truly time is the essence of the cost of drilling.

Concluding Statement

It may well be said then that what it costs to drill can be determined within reasonable bounds through modern cost accounting, provided the operation is such that essential time data from similar operations can be procured. Thus, through the application of a history of costs, the direct expense per day, the overhead per day, the drilling equipment depreciation expense per day, the drill pipe cost per day or per foot all become available for use in prognosticating the cost of future wells. Likewise there is available daily the material necessary to determine the most effective drilling practices and the information to point the way to improved operations. By taking itself out of the realm of the recorder of completed facts and by using those facts in the interpretation of current and future events modern cost accounting makes itself alive, vital, and potent. It serves its dual purpose, faithfully answering the question for both the present and future: "What Does It Cost to Drill?"

—— ☆ ☆ ☆ ——

Rationing Ad Infinitum

"Unless the administration is forced by Congress, before it is too late, to remove the shackles which its magicians in OPA have fastened on the oil industry, the public is going to receive the severest shock of all when it is told that rationing of oil may have to be continued for several years after the war because of the refusal of the bungling bureaucrats in OPA to realize that a price adjustment is necessary."

—Representative Winters of Kansas.

THAT'S WHAT THEY'RE BUILT FOR!

AMERICAN FULL ROLLER BEARINGS are made to exacting bearing requirements demanding the utmost in strength, durability and smooth, continuous performance under gruelling and abusive operating conditions. AMERICAN FULL ROLLER BEARINGS are carefully engineered, service-proven, time-tested. They are specially designed for extra heavy duty service and guaranteed to give flawless, trouble-free performance under the most severe strains and stresses encountered in the operation of modern heavy industrial machinery and equipment. Because they are built to outlast the equipment itself, few AMERICANS have ever failed in service.

Consult AMERICAN engineers on your next full-roller application.

AMERICAN ROLLER BEARING CO.
PITTSBURGH PENNSYLVANIA
Pacific Coast Office: 1718 S. Flower Street, Los Angeles, California

AMERICAN ROLLER BEARINGS HEAVY DUTY

AMERICAN
Heavy-Duty ROLLER BEARINGS

The "Big Inch" Pipe Line

☆ Why 24 in. was the only logical size— Will it be a postwar white elephant?

by Wallace R. Finney

Chairman, Special Engineering Committee, Petroleum Administration for War,

AND

J. B. Adoue, Pipe Line Engineer, Standard Oil Company (N. J.)

MUCH has been said and written of the "Big Inch," of the terrific obstacles encountered in its construction, of the colorful and tough men engaged in its building, but little has been publicized of the engineering and economic problems behind the scenes.

Long before Pearl Harbor it was apparent to the petroleum industry that a critical oil shortage could be expected along the Atlantic seaboard, owing to delay in tanker deliveries as a result of convoy movements, and to allocation of vessels for foreign shipments. This area, with a normal consumption of approximately 1,800,000 bbl. per day of oil and products, was almost entirely supplied by tanker. Pipe lines supplied an average of only 20,000 bbl. per day in 1939, 40,300 bbl. per day in 1940, and 55,000 bbl. per day in 1941. A small amount of oil and products was also delivered via barge.

After Pearl Harbor the tanker shortage became even more acute, necessitating increased movements by pipe lines and barges, with the major burden of the transportation placed upon the railroads. Rationing immediately reduced the average daily consumption, but the railroads still had to transport approximately 800,000 bbl. per day. This railroad movement represented a delivery of an average of 4200 cars per day, each car having a capacity of 8000 gal.

Railroad transportation was rapidly developed to a high point of efficiency, but basically it was not economical because of the high freight rate of $1.46 per bbl. from East Texas to the New York area. The tanker rates, including war risks, from the Gulf Coast to the same destination had reached 40 cents per bbl. and rates via existing pipe lines were 67½ cents per bbl. (The foregoing are rates and not actual costs of transportation.) Pipe line engineers, therefore, continued to urge construction of a large-diameter, high-capacity pipe line as a partial cure of the existing shortage.

As early as July, 1940, suggestions were advanced for construction of a large diameter or "Big Inch" pipe line from Texas to the Atlantic seaboard. In May of 1941, representatives of the major oil companies agreed on construction of a 24 in. crude oil line. In September, 1941, the National Defense Pipelines, Inc., was formed by 11 companies, proposing to finance and construct the line, but in October the Office of Production Management definitely turned down the project, refusing allocation of the necessary steel. However, the various oil companies continued their efforts. Nearly a year later, on June 10, 1942, the War Production Board finally approved allocation of steel for the first section of the line, which was to be built as an agency of the Defense Plant Corporation and known as the War Emergency Pipelines, Inc. Thus, the long-dreamed-of plans of pipe line engineers became a reality, and construction started August 3, 1942.

To illustrate the scope and size of this project, there follows a description and a map illustrating the area that it traverses.

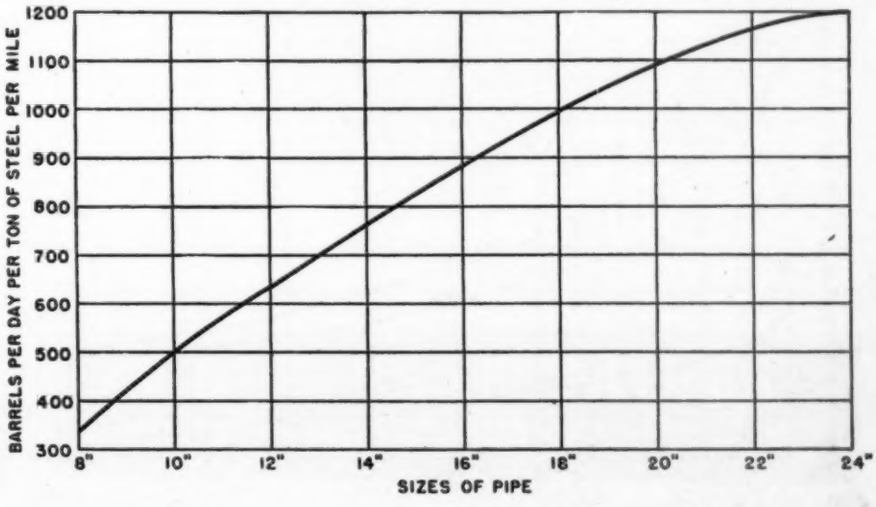
The main section of the line, 24 in. O.D., extends from Longview, Texas, to Phoenixville, Pennsylvania, a distance of 1253.7 miles. From Phoenixville a 20 in. O.D. line, 85.73 miles long, goes to Linden, New Jersey, where it enters a delivery system supplying the various refineries in the New York area. Also from Phoenixville, a second branch of the main line, consisting of 23.18 miles of 20 in. pipe, 10.5 miles of 16 in. pipe, and 3.75 miles of 14 in. pipe, feeds refineries in the Philadelphia area.

Between Longview, Texas, and Linden, New Jersey, the longest haul, is a distance of 1339.43 miles. From the accompanying map it will be noted that the line originating in Texas cuts across Arkansas, Missouri, Illinois, Indiana,

Fig. 1. Efficiency in steel requirements of crude oil pipe lines of various sizes, with stations spaced at an average distance of 50 miles.

Assumed data: Line gradient, 3 ft. rise per mile. East Texas crude, 75 S.S.U. (Saybolt Seconds Universal), 40° A.P.I. Station discharge pressures to be governed by pipe safety factor.

Size pipe, in.	Working pressure, lb.	Safety factor
8 (¼)	1000	3.47
10 (¼)	1000	2.79
12 (¼)	900	2.60
16 (¼)	750	2.52
20 (5/16)	750	2.52
24 (⅜)	750	2.52



*Published by courtesy of American Institute of Mining and Metallurgical Engineers. Appeared in *Mining and Metallurgy*, October, 1943.

Ohio, Pennsylvania, and terminates in New Jersey. By dotted lines is shown the previous transportation via existing pipe lines from the East Texas field to Texas Gulf Coast points, a minimum distance of 200 miles, thence by tanker water route, a distance of 1885 miles, to the Bayway, New Jersey, water terminal on the Arthur Kill River adjacent to Linden. Hence, the former total distance in transportation was 2085 miles via pipe line and tanker compared with 1339.43 miles via the "Big Inch."

In the minds of many persons, in particular engineers of all professions, certain questions have arisen concerning this project. Here are some that have been asked:

(1) Why a 24 in. pipe line—why not a smaller or larger size?

(2) Why a capacity of 300,000 bbl. per day? How many pumping stations, using what type of equipment, would be involved?

(3) What would be the cost of construction and what would be the transportation costs via such a line?

(4) Would a "Big Inch" pipe line be an economic white elephant to be abandoned after the war?

First, as to the question of the relative size of the line, it must be remembered that our country was at war and maximum efficiency in the use of critical materials was a prerequisite. That is, we must transport the maximum quantity of oil per ton of steel used, per horsepower of motive power required. Table 1 is a tabulation and Fig. 1 a curve pertaining to lines of various sizes outside diameter.

From the data in Table 1 on barrels of oil transported per day, per ton of steel used, and per horsepower required at each station, it is quite apparent that a 24 in. line provides more efficient means of transportation than do the smaller sizes. An 8 in. line, for instance, will transport 339 bbl. per day per ton of steel per mile, compared with 1200 bbl. per day for a 24 in. line. Similarly, an 8 in. line will move 45.9 bbl. per day per horsepower at each station, in comparison with 67.4 bbl. for a 24 in. line. Thus, from the standpoint of efficient use of critical materials, the larger diameter line is far superior.

TABLE 1
Line capacities based on East Texas crude
(Stations spaced 50 to 55 miles apart average)

Size of line, in. O. D.	8⅝	10¾	12¾	16	20	24
Capacity per day, bbl	20,000	37,000	56,000	98,000	190,000	300,000
Working pressure, maximum, lb.	1,000	1,000	900	750	750	750
Wall thickness, in	¼	¼	¼	¼	⅝	⅝
Safety factor	3.47	2.79	2.6	2.52	2.52	2.52
Weight per ft.-lb	22.36	28.04	33.38	42.05	65.71	94.62
Tons steel per mile	59,030	74,026	88,123	111,012	173,474	249,797
Pump efficiency, per cent	78	79	80	82	84	86
Pump hp. required per station	436	796	1070	1525	2885	4450
Bbl. per day per ton of steel per mile	339	500	635	889	1095	1200
Bbl. per day per hp. per station	45.9	46.5	52.3	64.2	65.9	67.4

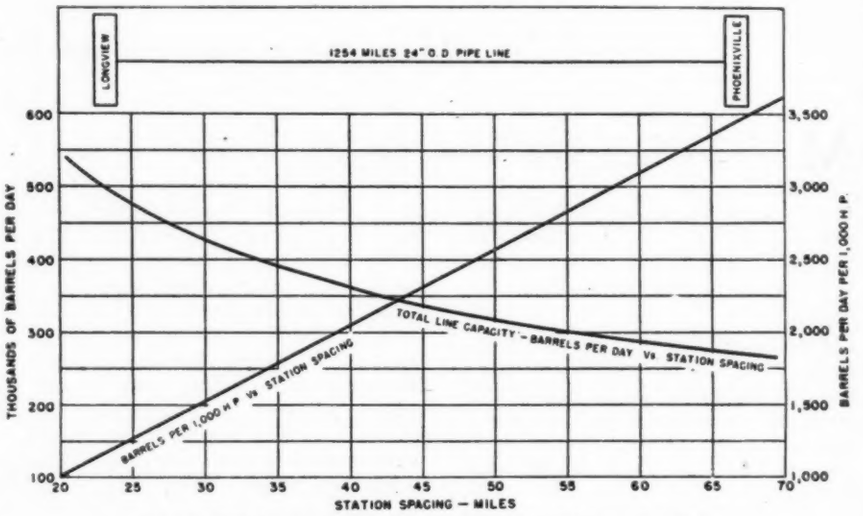

LONGVIEW
1254 MILES 24" O.D. PIPE LINE
PHOENIXVILLE
THOUSANDS OF BARRELS PER DAY
BARRELS PER DAY PER 1,000 H.P.
TOTAL LINE CAPACITY - BARRELS PER DAY Vs STATION SPACING
BARRELS PER 1,000 H.P. Vs STATION SPACING
STATION SPACING — MILES

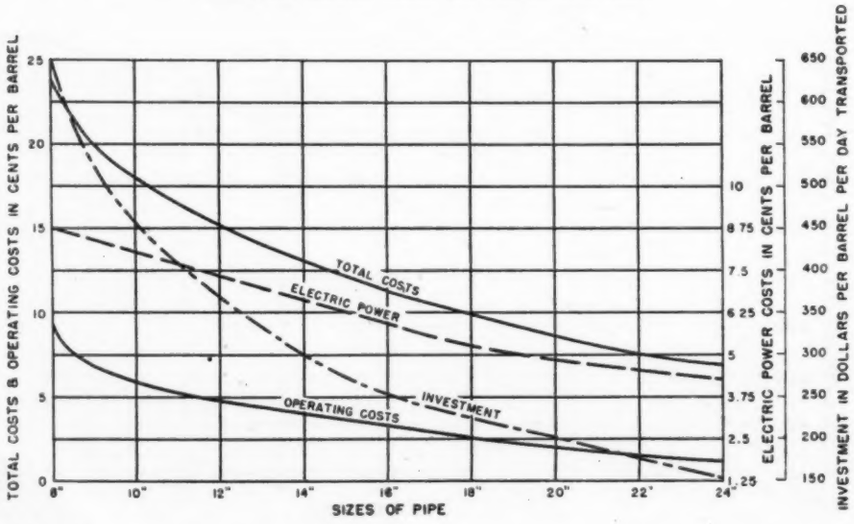
Fig. 3. Efficiency in station spacing for 24 in. pipe line

Next, with reference to the comparable cost of transportation for various size lines from 8 to 24 in., Fig. 2 shows an estimate of such costs including operating expense and electric power costs, plus ad valorem taxes of 1.25 per cent, and depreciation at 3.25 per cent. Summarizing the data illustrated on this chart, for a line 1000 miles long, a 24 in. line will require an investment of $158 per bbl. transported per day, a 20 in. line $205, a 16 in. line $256, a 12 in. line $366, and an 8 in. line $650. In other words, a 24 in. line, from an investment standpoint per barrel transported, is by far the most desirable of the sizes considered.

Next, from an operating standpoint, the total cost for transporting oil 1000 miles is 23.6 cents for an 8 in. line, 15.3 cents for a 12 in. line, 11.3 cents for a 16 in. line, 8.6 cents for a 20 in. line, and 7 cents for a 24 in. line. So the cost with an 8 in. line is 3.37 times greater than with the 24 in. line. Approximately the same personnel is required for a 12 in. as for a 24 in. line.

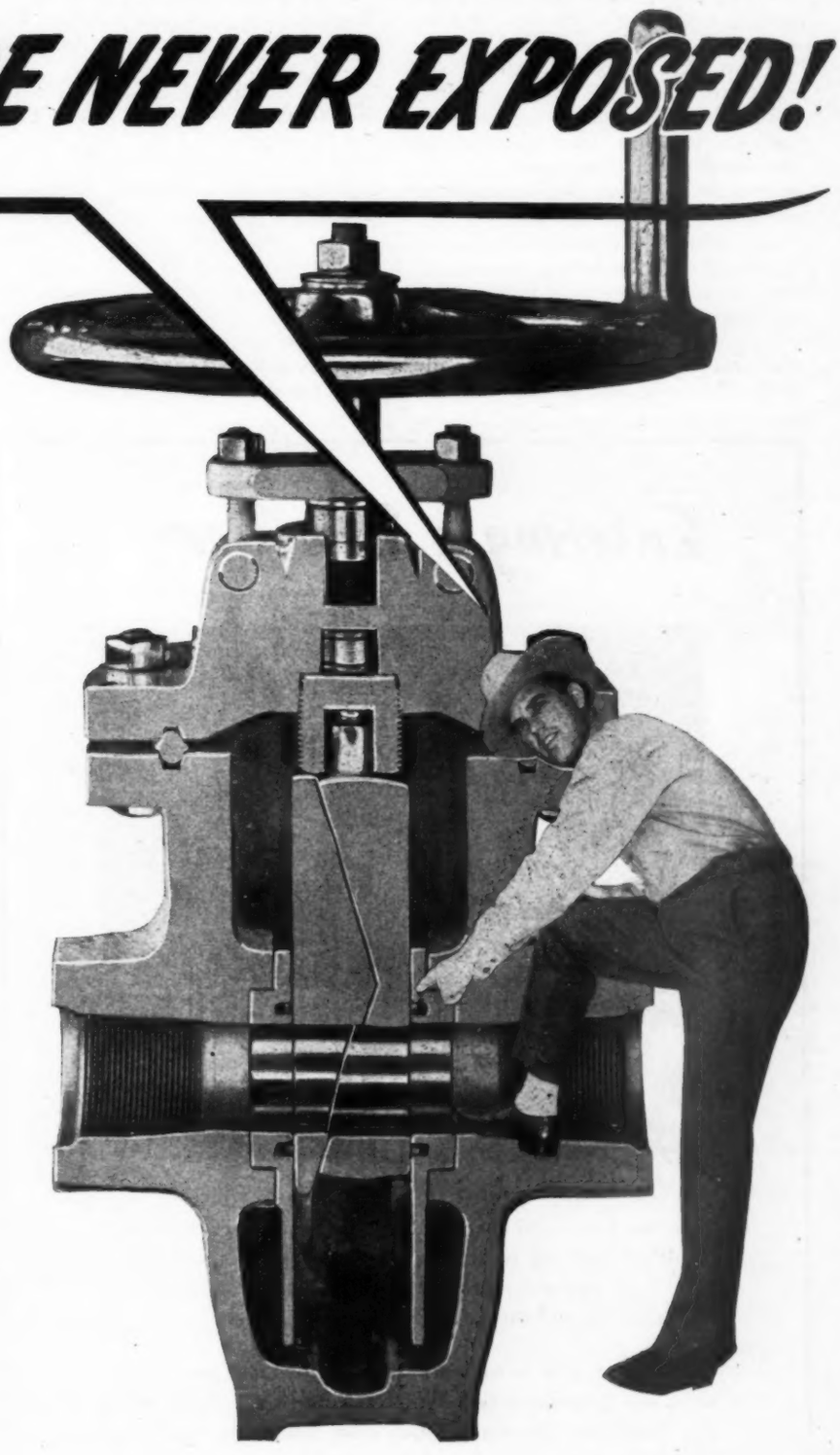
Investigations of the cost of motive power disclosed numerous advantages in the large line. First, the higher electric load earns a lower power rate per

Fig. 2. Investment and operating costs of crude oil pipe lines of various sizes, based on a single line 1000 miles long, using electrically driven centrifugal pumps, with stations spaced 50 miles average. Operating costs include labor, maintenance, communication expense, and office salaries. Total costs include operating costs plus electric power, ad valorem taxes, and 3¼ per cent depreciation, but excludes income and transportation taxes


TOTAL COSTS & OPERATING COSTS IN CENTS PER BARREL
ELECTRIC POWER COSTS IN CENTS PER BARREL
INVESTMENT IN DOLLARS PER BARREL PER DAY TRANSPORTED
TOTAL COSTS
ELECTRIC POWER
INVESTMENT
OPERATING COSTS
SIZES OF PIPE

OPEN OR CLOSED, W-K-M GATE VALVE

SEATS ARE NEVER EXPOSED!



Here is one of the big reasons why W-K-M Gate Valves are regarded as the soundest valve investments in the oil country. *The seats are positively protected against cutting in both open and closed position!*

Note in the cut-away view presented here how the seat faces are never exposed to pressure or damage . . . regardless of whether the valve is in open or closed position. Note, also, the patented bronze combination wipe-and-seal rings which contact both sides of the gate so that the seat faces are wiped clean with each operation of the valve. Pressure never enters the valve body, which is packed with grease to permit easy operation of the valve and to protect the internal parts against corrosion or scale. Thus, foreign matter can neither be deposited on the seat faces nor settle out in the valve body to prohibit full closure. The complete elimination of all irregularities and cavities in the cylindrical, full opening flow-way prevents turbulence, and, as a result, cutting is eliminated.

Numerous other mechanical refinements contribute to the popularity of W-K-M Gate Valves. Complete details will gladly be furnished interested operators on request. W-K-M Company, Houston, Texas. Export Office: 74 Trinity Place, New York, N. Y.

4000 lbs. tubing flow pressure on this well makes choke changing a frequent operation. W-K-M Gate Valves on the flow wings of this manifold open and close with ease and provide absolute control at all times.

W·K·M GATE VALVES

Cost No More than Ordinary Valves

kw-hr. Second, the motors and pumps provide a much higher efficiency as a result of the increased capacity.

From these figures it is clearly apparent that the high efficiency in transportation is obtained through a single large-diameter line. Then why was not the size of the line increased to 30 in., or even 36 in.? There were a number of limiting factors. For example:

(1) The War Production Board stipulated that pipe used in this project must be made from steel billets. This automatically required use of seamless pipe, as electric-weld pipe is made from plate, supplies of which were critically short. Only one mill in this country was equipped to make seamless pipe as large as 24 in. in outside diameter. This in itself, limited the line to a maximum size of 24 in.

(2) The question of supply also limited the line to a 24 in. size. Careful investigation of the production in East Texas, with further deliveries via pipe line from other fields, disclosed a maximum possible supply of approximately 300,000 bbl. per day. This could be efficiently handled by a 24 in. line.

(3) No construction equipment was available suitable for laying anything larger. Much of the available equipment even had to be remodeled and revised for handling this size pipe.

Entering a New Year—

Our No. 1 job is to keep vital electric power service flowing to all oil and war industries. Hundreds of electric installations feed our electric energy to all phases of the highly important oil industry.

Our No. 2 job is to work with fellow citizens to preserve our democratic system of free enterprise, so that when our American men and women come home, they will find an opportunity to work and to enjoy the rewards of their labor. We must keep America American. This is our duty under the heritage of our American Constitution.

SOUTHWESTERN
GAS AND ELECTRIC COMPANY

Capacity was the next problem. Why 300,000 bbl. per day? Could this capacity be efficiently handled through a 24 in. line? If so, how many and what type stations would be required? The answer to the first question has already been discussed in the foregoing paragraph No. 2. Fig. 3 demonstrates how a 300,000 bbl. capacity is within the range of most efficient capacity for a 24 in. line. This chart shows that the capacity of a line is directly dependent upon the number and spacing of stations. Let us consider the main 24 in. line section between Longview, Texas, and Phoenixville, Pennsylvania, a distance of 1254 miles. With 25 stations spaced approximately 50 miles apart we would obtain a capacity of 335,000 bbl. per day. With 24 stations spaced an average of 52.2 miles apart a capacity of 320,000 bbl. is indicated.

This latter station spacing is more desirable in that it provides a small excess of capacity as a safety factor against capacity reductions caused by higher viscosity of oil during the winter months. This station spacing is also in the higher range of efficiency in transportation from the standpoint of barrels transported per day per 1000 hp. of motive power. For a capacity of 300,000 bbl. per day, the curve indicates that a station spacing in the range of from 50 to 60 miles would be desirable for efficiency. With an average spacing of 52.2 miles, 24 stations are required between Longview and Phoenixville. Station No. 25 is at Phoenixville and pumps to Station No. 26, which delivers to Linden, the terminus of the line. Station No. 25 also pumps through the branch delivery system to refineries in the Philadelphia area. Hence, for a total system comprising approximately 1377 miles of pipe line, 26 main pumping stations are required plus one receiving terminal at Linden, involving a total of roughly 118,800 hp.

Compare this total motive power with that of tanker deliveries from Gulf Coast points to the same terminus in New Jersey. To maintain this average delivery of 300,000 bbl. per day, a total of 34 to 36 tankers with an average capacity of 116,000 bbl. each would be required. The motive power via tanker would be more than double that required by the 24 in. pipe line.

The next item of interest is the stations—their type, motive power, and pumping equipment. Basically, each station consists of three units operating in series. Each unit is composed of a large, single-stage, double-suction centrifugal pump directly connected to a 1500 hp., 2300 volt induction motor. Each pump, at a capacity of 300,000 bbl. per day, develops approximately 235 lb. pressure—or with three pumps

in series a pressure of about 700 lb. is obtained.

Most remarkable feature of these pumps is their high efficiency—86 per cent—which approaches the efficiency of positive displacement plunger pumps. Centrifugal pumps used in all prior pipe lines so equipped were of the multi-stage type giving an efficiency of not over 78 per cent. The additional 8 per cent efficiency alone represents a saving of about $450,000 per year in electric power cost. The motors, of 1500 hp. each, also were of increased efficiency —95 per cent—and with a power factor of 0.926 likewise provided a material saving in electrical power.

The stations, by use of three single-stage pumps in series, provide a simple piping arrangement. Fig. 4 shows a diagrammatic arrangement of a typical station. It is immediately apparent why such stations can be operated with a minimum personnel, which consists of only nine men per station. Thus high-capacity stations of maximum efficiency are operated with minimum personnel, resulting in low operating costs.

Perhaps the next question is what will be the cost of construction of the "Big Inch." In the original estimates the cost of the line was set as high as $90,000,000, which, as the construction nears completion, appears high. It is now indicated that the total cost will be between $75,000,000 and $80,000,000 for the complete system. Much credit for the savings accomplished is due the entire organization. Using a base figure of $75,000,000 as the investment, the cost of transportation via the "Big Inch" is now estimated as shown in Table 2.

TABLE 2
Cost of transportation by new pipe line

	Cents per bbl.
Operation expense including maintenance	1.2
Administrative and general expense	0.3
Electric power	5.7
Ad valorem taxes	1.0
Total cash operating expense	8.2
Depreciation at 3¼ per cent	2.2
Total	10.4

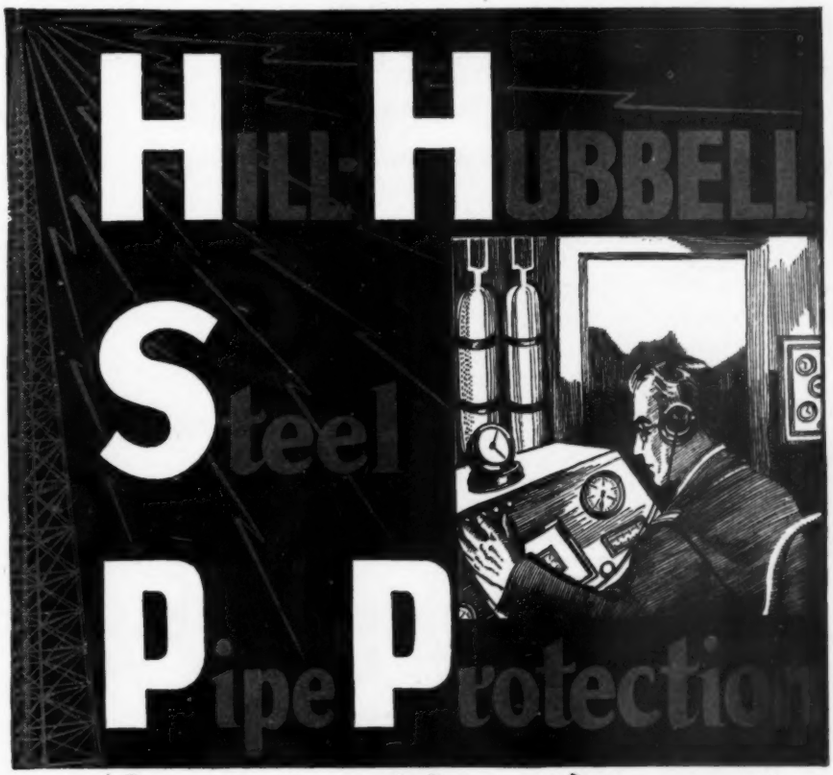
If the "Big Inch" were a private concern, allowed 7 per cent earnings with payment of 45 per cent income tax thereon, plus a transportation tax at 4½ per cent, the following would be added:

	Cents per bbl.
Earnings 7 per cent	4.8
Income tax at 45 per cent	3.9
Transportation tax at 4½ per cent	0.9
Grand total	20.0
Deduct earnings at 7 per cent	4.8
Net cost of transportation	15.2

Never in the history of pipe line operations have such low costs even been approached and a new era of pipe line activities is clearly in sight. Compare this cost with present railroad freight rates of $1.46 per bbl., and present pipe line tariffs via existing small-diameter pipe lines of 67½ cents, and a remarkable saving in transportation costs is demonstrated.

This, of course, brings up the last question: Is the "Big Inch" a white elephant to be abandoned as another war project? The answer is definitely NO! In proof of this answer the following facts are illustrative.

The major competition to the "Big Inch" is, of course, transportation via tankers, the cost of which from the Gulf Coast terminals to New Jersey in tankers of the most modern design is approximately equal to the net cost of transportation as indicated in Table 2. To this must be added the cost of loading and unloading, that is, terminal costs, as well as the cost of pipe line movements from the producing field to Gulf Coast terminals. In view of the fact that considerable quantities of crude for the "Big Inch" will come



••*is "on the beam"*••

We're lining up for the post war formation to serve the gas and oil industries.

Streamlined production will put us squarely "ON THE BEAM" to supply you with *factory process* HILL-HUBBELL STEEL PIPE PROTECTION.

Hill-Hubbell Steel Pipe Protection is being currently applied at these leading mills.

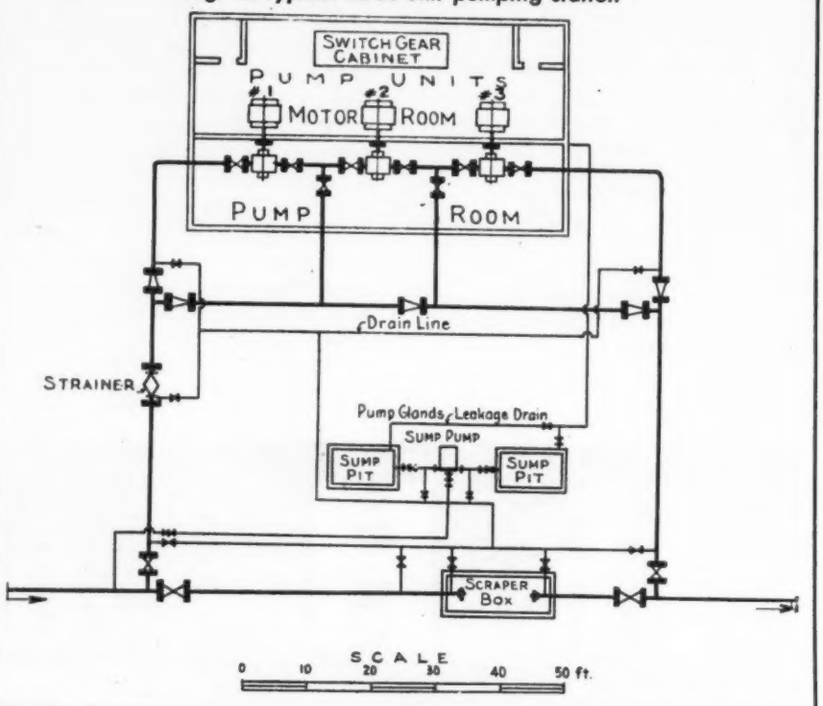
Jones and Laughlin Steel Corporation

National Tube Company

Spang - Chalfant

GENERAL PAINT CORPORATION
HILL, HUBBELL & CO. • Division • Cleveland, Ohio
• EXPORT OFFICE: SAN FRANCISCO, CALIFORNIA, U. S. A. •

Fig. 4. Typical three-unit pumping station



from fields other than East Texas, the comparable cost in transportation should be based from East Texas to New York or from Gulf Coast terminals to New York, as an approximate equal cost would occur in transportation from such other fields to either East Texas, point of origin of the "Big Inch," or to Gulf Coast terminals for loading on tankers. Of course, the water terminal costs in loading and unloading would be saved, for they do not exist in the instance of the "Big Inch."

After the war, operation of tankers will, of course, provide the major capacity required along the Eastern seaboard, but the "Big Inch" will be operated permanently. It will provide not only low-cost transportation, but will have the further beneficial effect of acting as a cushion on tanker rates, which in years past have fluctuated widely.

So a new era of pipe line operations has dawned and the "Big Inch" will establish itself as a wise business enterprise and one which from continued operation will prove the sound engineering and economics upon which it was developed and built.

—— ☆ ☆ ☆ ——

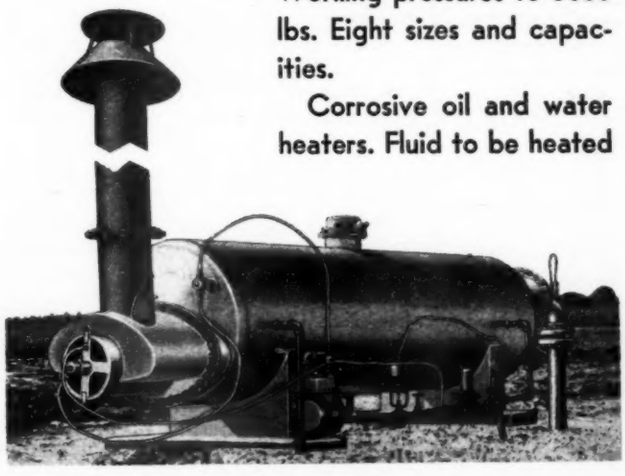
Route of the line and comparison of its length with distance of tanker water route to the east

HEATERS—

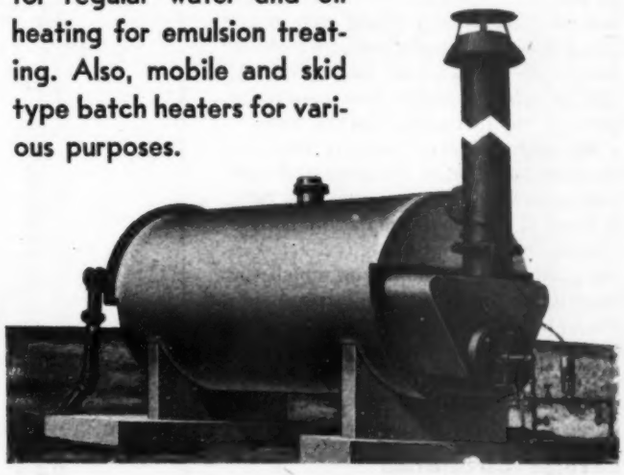
Gas heaters for use in hydrate prevention, and for other gas heating requirements. Indirect coil type heaters, wherein high pressure gas coil is heated in hot water bath. Safe, dependable operation at all pressures. Automatic control of heating furnace. Removable coils and firebox. Working pressures to 3000 lbs. Eight sizes and capacities.

Corrosive oil and water heaters. Fluid to be heated circulated through corrosion resisting cast iron coil immersed in automatically heated hot water bath. Coils and furnace easily removed for cleaning or repair. Working pressures to 200 lbs. Made in eight sizes and capacities.

Other types of heaters for regular water and oil heating for emulsion treating. Also, mobile and skid type batch heaters for various purposes.



Indirect Gas Heater



Indirect Liquid Heater

EACH NATIONAL TREATING AND HEATING UNIT IS EQUIPPED WITH REMOVABLE FURNACE

Horizontal Type Direct Liquid Heater

OTHER NATIONAL PRODUCTS INCLUDE

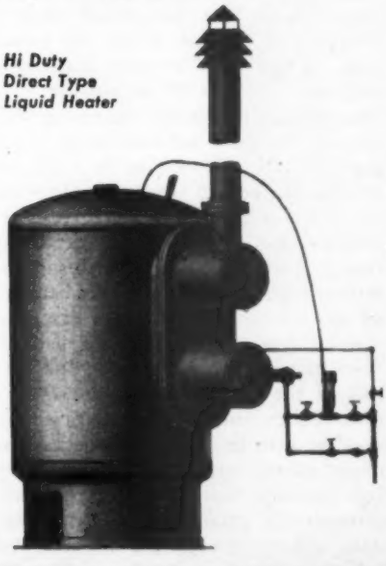
- OIL AND GAS SEPARATORS
- EMULSION TREATING UNITS
- BOLTED TANKS
- WOOD TANKS

AND MANY OTHER PRODUCTS FOR THE OIL INDUSTRY.

Catalogs available on these products by request.

Write for Catalogs

Hi Duty Direct Type Liquid Heater



Gravel Packing Wells

PETROLEUM ENGINEER Exclusive Feature

☆ New equipment and method indicative of progress in economic field operation

by C. C. Pryor
Associate Editor

GRAVEL packing has found widespread application in wells for the production of oil and/or gas and injection of water and gas into formations. The three principal purposes of gravel-packing the space between the wall of the well and the liner with screened gravel particles of any desired size are: to prevent sloughing of the formation into the hole, which would stop or restrict flow; to prevent plugging of the liner with particles of the formation, and to provide proper flow conditions between the formation and the liner.

Methods of gravel packing now extensively used may be separated into two general divisions, as they vary only in detail. The reverse circulation method consists of injecting the gravel between the casing and the tubing on which the liner is run, and returning circulation through the tubing. Normal circulation consists of pumping the gravel down through the tubing and returning circulation through the annulus between casing and tubing.

Reverse Circulation

Gravel packing of wells by the reverse circulation method usually requires underreaming below the casing seat, which provides sufficient annular space around the liner to permit free passageway for the gravel without bridging of the hole below the casing seat. As the space between the casing and liner will always be smaller than any enlarged hole below the casing seat, the size of casing and liner becomes important and care should be taken to provide the largest space possible when the gravel is injected by the reverse circulation method. The liner is usually run on a string of tubing with suitable setting tools or connections for backing off the tubing from the liner after the annular space has been gravel packed. With the liner in position on the bottom of the well for gravel packing by reverse circulation, the circulation fluid —oil or a drilling mud—is injected into the annular space between the casing and tubing, down behind the liner through the perforations in the liner shoe, and up through the inside of the tubing to establish circulation. Usually a thin cement lining is run on the inside of the perforated liner to close the perforations and allow the fluid to circulate down behind the liner to the perforated shoe on the bottom of the liner. Utilizing free circulation the gravel is introduced into the circulating fluid by gravel pumps and/or a pressure gravel lubricator. The gravel is deposited behind the liner and the fluid returned to the surface. Probably the greatest difficulty in using the reverse circulation method for gravel packing is bridging of the gravel in the restricted space between the tubing and casing above the liner. This action sticks the tubing and often results in an expensive fishing job to recover the tubing. In addition there is the hazard of hole sloughing or caving partially due to agitation while circulating an improper drilling fluid in and out of the well across the face of the enlarged open hole below the casing seat. Such action usually results in bridging of the gravel back of the liner before the entire space has been filled with gravel. This problem requires pulling the tubing and liner and cleaning the hole before again attempting to gravel pack.

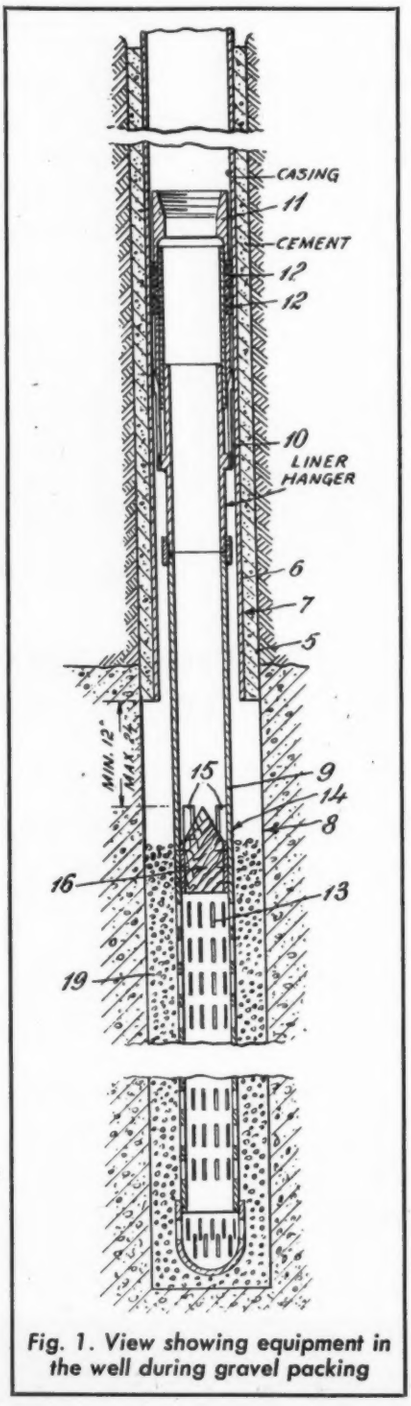


Fig. 1. View showing equipment in the well during gravel packing

Normal Circulation

When using the normal circulation method to gravel pack a well, the hole is underreamed below the casing seat, and the liner set in place in the hole with tubing. The fluid is pumped down the tubing, through the liner, through the check valve placed in the bottom of the liner, and then returns to the surface through the annular space. Action of the check valve prevents the gravel from returning to the liner after the pumps have been shut down on the surface.

The normal circulation method reduces the possibility of the gravel bridging due to caving behind the liner, because the fluid, as it circulates behind the liner, lifts the cavings and carries them up behind the liner as the gravel comes into the hole from the tubing, the liner, and through the liner check valve. The possibility, however, of the gravel bridging in the tubing and/or liner above the check valve is still prevalent in this method.

New Method

A patented gravel packing apparatus and method in which the difficulties of present methods have been avoided to a large degree have been developed. The method and equipment eliminates the use of tubing. The full interior area

of the casing is utilized for passage of gravel, the washing action of circulated fluids upon the formation being packed is minimized, and only a minimum of operative steps is required. The method and apparatus have been used successfully in the East Texas field for producing and injection wells.

In Fig. 1 is shown a sectional elevational view of the apparatus in the well during gravel packing. Fig. 2 is an enlarged view of the portion of tube 9 of Fig. 1 containing plug 16 and ports 15 showing details of construction. Fig. 3 shows a cross-section of Fig. 2 taken along line A—A looking in the direction indicated. After the gravel packing is completed plug 16 is displaced and the well is produced through the tubing 20 as shown in Fig. 4. In Fig. 1, 5 indicates the bore of the well, in which the casing 6 has been seated and cemented at 7. After being cased the well has been underreamed to increase its diameter below the casing seat as shown at 8. A suitable liner 9 has been placed in the underreamed hole 8 and positioned by means of liner hanger 10, terminating at its upper end in a coupling 11, the whole being supported in and packed to the casing by a conventional liner hanging packer 12.

The liner is provided with slots 13, as is usual for production, these slots extending throughout a desired portion of the length of the liner. At a point 14, above the production slots, but at a point below the bottom of the casing 6, there is provided in liner 9 a construction best understood by referring to Figs. 2 and 3, wherein the liner 9 is shown to be equipped at level 14 with three large slots or "windows" 15, distributed as shown in Fig. 3, which is a section of the liner at A—A. Below these windows and within liner 9 is a cone-topped plug 16, supported within the liner by pins 17. This plug may be made as shown of wood, Bakelite, or any frangible material that may later be broken or removed by drilling, or that may be pushed to the bottom of the liner. If desired, the plug may be encased in a metal sleeve 18. The cone-shaped top of plug 16 is so placed rela-

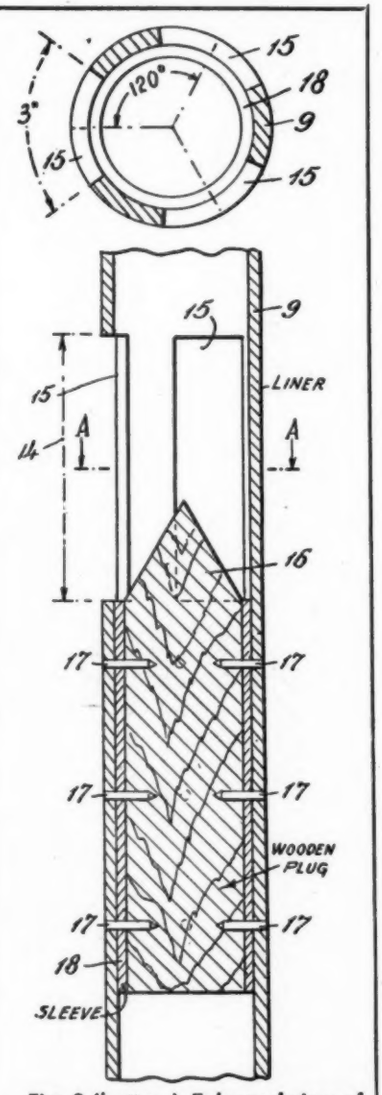


Fig. 2 (bottom). Enlarged view of portion of tube 9 of Fig. 1 containing plug 16 and ports 15, showing details of construction.

Fig. 3 (top). Cross-section of Fig. 2 at line A-A.

IT'S NO MILITARY SECRET!

Why thousands of Martin Plungers are most successful in fighting the Battle of Oil Production on the Home Front; combating Salt Water, Sand, Corrosion, tube wear and other enemies which slow down the producing of oil from your pumping wells.

It's the *Simplicity of the Martin Design*—accurately machined grooves in a One-Piece Body — which rigidly hold in place the special Wear-Resistant Martin Rings—so that they can give their full life service—a patented Martin feature.

Available for all makes and sizes of oil well pumps.

3¾" x 36" Groove Martin Plunger Body Without Rings

Write for Illustrated Catalog . . . or See Composite Catalog

SOLD ONLY THROUGH SUPPLY STORES

JOHN N. MARTIN
Manufacturer
11 W. Brady St. Tulsa, Okla.

Field Representatives

Tom Hulett, El Dorado, Ark.
C. J. Baeten, Wichita, Kans.
Lynn C. Holloway, Houston, Texas
Hugh Robinson, Blackwell, Okla.
F. M. Wilson, Wichita Falls, Texas
J. Walter Wade, Chicago, Ill.
E. C. Dilgarde, Casper, Wyoming

tive to the slots 15 that it forms a directive slope whereby material such as gravel, will be forced to pass entirely out through the slots.

Fig. 1 shows the liner and packer set and the tubing entirely removed. A mixture of gravel and a small amount of fluid is dropped into the casing at the surface. In a non-flowing well, the fluid may be oil or a petroleum fraction. In salt water disposal wells the fluid may be water. In an oil well under pressure, the fluid may be oil and the mixture may be introduced at the surface through a proper lubricator. When the gravel reaches the bottom of the casing it passes out through the slots 15, to collect around the liner as shown at 19. This procedure is followed until a sufficient amount of gravel has been placed behind the liner. The excess gravel inside the liner, above the plug, after filling the annular space is removed with a suitable bailer. Plug 16 and sleeve 18, if the sleeve is used, are drilled out or driven to the bottom of the liner 9.

A string of tubing, 20 on Fig. 4, is run into the well to complete it. The string of tubing 20 ends in an adaptor 21, carrying an adaptor packing 22, that is set down on the coupling 11 of the liner hanger 10. From the adaptor 21 is a tubing 23, which is of slightly smaller external diameter than the internal diameter of liner 9 and extends into liner 9 a sufficient distance to ex-

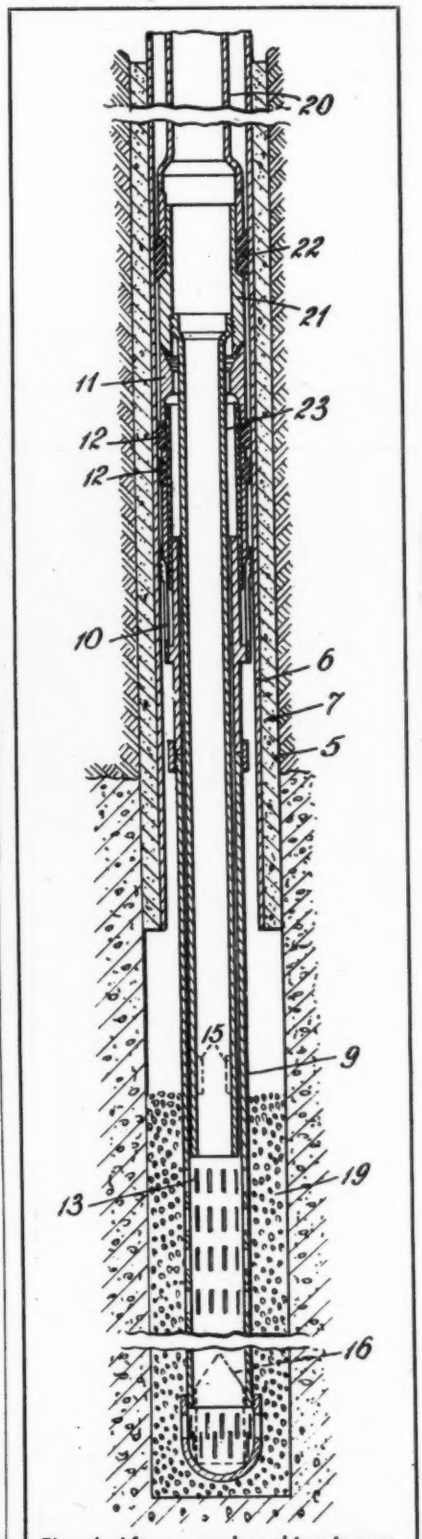
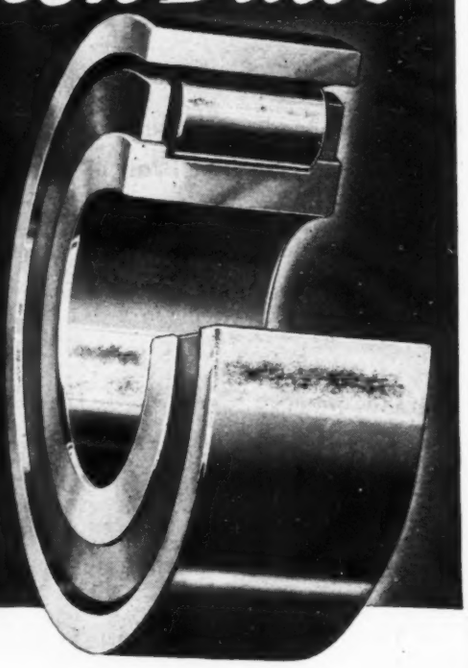


Fig. 4. After gravel packing is completed plug 16 is displaced to bottom of liner and the well produced through tubing 20 and liner slots 13 as shown above. Tubing 23 blanks off the slots 15

Precision Built FOR RADIAL LOADS



AMERICAN ROLLER BEARINGS

AMERICAN RADIAL ROLLER BEARINGS are *precision built* for almost every heavy-duty bearing application where the load is radial. Use of AMERICANS in heavy machinery lowers maintenance costs and increases the performance-life of vital equipment. AMERICAN RADIAL ROLLER BEARINGS are readily adaptable because the outer race is removable for easy assembly. Rugged durability and long life are assured by special heat-treated alloy steel. Constant inspection and precision tests make for absolute accuracy and smooth, quiet performance. AMERICAN RADIAL ROLLER BEARINGS are made in five styles, 4 S.A.E. series and 85 sizes. Special designs to your requirements are also available. Write today.

AMERICAN ROLLER BEARING COMPANY
PITTSBURGH PENNSYLVANIA
Pacific Coast Office: 1718 S. Flower St., Los Angeles, Calif.

AMERICAN
Heavy-Duty ROLLER BEARINGS

tend beyond and blank off the slots 15 in liner 9.

Features of Method

There are four outstanding features of the equipment and method of gravel packing wells just described.

1. The hazard of sticking the string of tubing by gravel bridging above the liner is eliminated.
2. The possibility of gravel bridging due to restricted space between casing and liner is eliminated.
3. If gravel bridges above the wooden plug in top of the liner it can be removed readily with a bailer, thus eliminating the job of pulling the tubing.
4. The possibility of gravel bridging back of liner because of caving conditions is reduced because the fluid used to inject gravel back of the liner is pumped into the surrounding formation and thereby maintains a constant pressure on the face of the open hole and partially eliminates the washing action of the circulating fluids.

☆ ☆ ☆

Association Elects

Ralph B. Lloyd, president of the Lloyd Corporation, Ltd., was reelected president of the California Oil and Gas Association for a third term at the December meeting of the association's board of directors. A. C. Mattei, president of the Honolulu Oil Corporation, and Reese H. Taylor, president of the Union Oil Company of California, were elected vice presidents. C. A. Johnson, president of the Holly Development Company, was elected treasurer. F. E. Foster continues as managing director, and D. S. Kilgour as assistant manager.

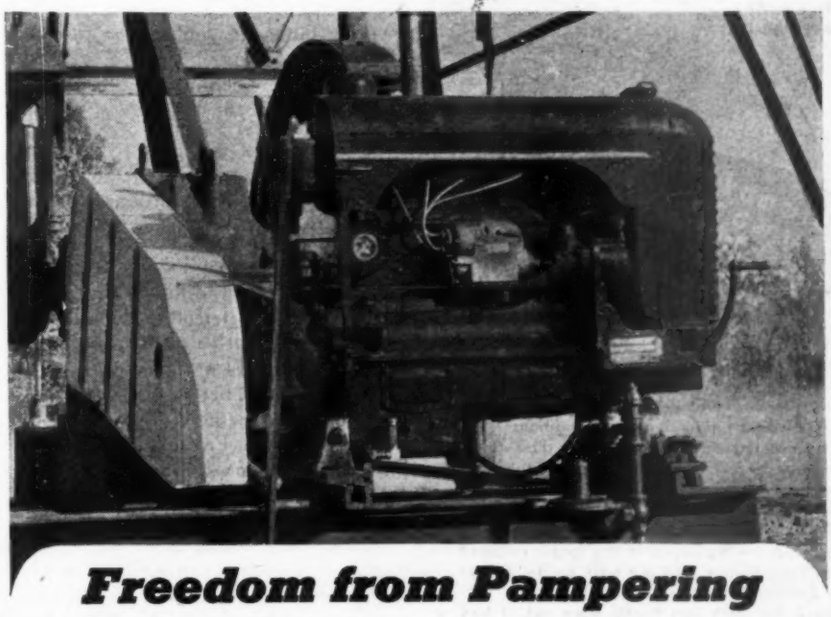
Directors elected for 1944 include: Leigh M. Battson, c/o Robert S. Lytle, operator; S. Belither, chairman, Shell Oil Company, Inc.; James B. Black, president, Pacific Gas and Electric Company; H. D. Collier, president, Standard Oil Company of California; R. E. Collom, vice president, Continental Oil Company; J. A. Crawford, president, Youngstown Steel Products Company; S. J. Dickey, president, General Petroleum Corporation of California; E. S. Dulin, president, Byron Jackson Company; LeRoy M. Edwards, vice president, special counsel, Southern California Gas Company; E. B. Gilmore, president, Gilmore Oil Company; Dana Hogan, president, Hogan Petroleum Company; R. P. Huggins, general manager, Western Gulf Oil Company; Wm. F. Humphrey, president, Tide Water Associated Oil Company; C. S. Jones, president, Richfield Oil Corporation; W. M. Keck, president, Superior Oil Company; Wm. Reinhardt, vice president, Union Pacific Railroad; F. C. Ripley, manager, Chanslor-Canfield Midway Oil Company; L. P. St. Clair, president, Independent Oil Producers' Agency; J. B. Sutherland, division manager, Ohio Oil Company; C. P. Watson, vice president, Seaboard Oil Company of Delaware; Torrey H. Webb, vice president, The Texas Company; A. L. Weil; Lee K. Whittier, treasurer, Belridge Oil Company, and W. C. Whaley, vice president, general manager, Barnsdall Oil Company.

Manages L. A. Office

The Joshua Hendy Iron Works, Crocker-Wheeler Electric Division, announces the appointment of R. D. Ulrey as manager of the new Los Angeles, California, office.

This new office will provide coverage for Southern California, Arizona, and New Mexico. By the establishment of this office, users of Crocker-Wheeler motors, generators, and flexible couplings will be more promptly served in that area, it is stated. The office is in the Pacific Mutual Building, 523 West Sixth Street, Los Angeles.

Ulrey is well known in that area as a motor and generator application specialist, having been associated with U. S. Electrical Motors of that city.



Freedom from Pampering

WORKING day after day, month after month . . . sometimes year after year . . . without shut-down for service attention is a habit of Case Oilfield Engines that pays double dividends in these days. It makes the most of the oil in the well, and of manpower for attendance.

Pressure lubrication from the crankcase is so complete that hand greasing is reduced to a minimum. Continuous oiling and exceptionally effective protection against dust and dirt prolong the life of vital parts and postpone the need for renewal or adjustment. Plenty of wear-resistant materials and parts has its share, too, in the long working life of Case Oilfield Engines.

When a little care goes such a long way, be sure that your Case Oilfield Engines get that little care consistently. Get all the extra endurance and sustained economy built into them. When you have need of more pumping power, ask your Case distributor about the possibility of supplying you. J. I. Case Co., Racine, Wis.

DISTRIBUTORS

Southwest Equipment Co., Dallas and Kilgore, Texas
Leland Equipment Co., Tulsa, Oklahoma

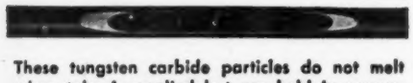
CASE KEEP ON BUYING WAR BONDS

Tube Borium Keeps 'em digging

STOODY TUBE BORIUM* KEEPS DITCHER TEETH SHARP ...ELIMINATES FREQUENT SHUT-DOWNS FOR TOOTH CHANGES...CUTS REPLACEMENT COSTS UP TO 75%

The two ditcher teeth pictured above were used on the same machine and operated under identical conditions.
The unprotected tooth at the top had to be sharpened every three days and was too short for further service after six sharpenings.
But the Borium-protected tooth at the bottom operated for 40 days and wore only ½". It was simply resharpened in the forge, retipped with Tube Borium, and put back on the ditcher for another 40 days' service.
Before the tooth was finally worn out, it had operated a total of 120 days!
Tube Borium makes such savings possible because the deposits represent the ultimate in wear resistance and the ability to cut hard earth formations.

*Stoody Tube Borium is supplied in rods of ⅛", 3/16", ¼" and ⅜" diameters and is available for either oxyacetylene or D.C. electric application. Prices and specifications are yours for the asking.



These tungsten carbide particles do not melt when tube is applied but are held in suspension in a mild steel matrix forming a deposit resembling coarse sandpaper.

Send for free booklet on TUBE BORIUM, showing sizes and styles of rods and recommended methods of application.

STOODY COMPANY
1142 West Slauson Ave., Whittier, Calif.

STOODY HARD-FACING ALLOYS
Stop wear... Eliminate Repair

LAUGH WITH BARNEY

"Your wife has been delirious all day," said the nurse, in a worried tone, "calling for you and crying for money."

"Hah," snorted friend husband, "Delirious, hell!"

"I saw you the other day at the corner winking at the girls."

"I wasn't winking. That's a windy corner. Something got in my eye."

"She got into your car, too."

Boss: How did you happen to oversleep this morning?"

Office Boy: There were eight of us in the house and the alarm was set for seven."

"They laughed when I sat down, but how did I know the bathroom door was open!"

"The night school doesn't seem to do John a bit of good in his English," said Clara of her boy friend. "He still ends every sentence with a proposition."

Mother: Now, before you get serious with him, be sure he is always kind.

Daughter: Oh, I'm sure he is. I heard him say he put his shirt on a horse that was scratched.

The demure young bride, her face a mark of winsome innocence, slowly walked down the church aisle, clinging to the arm of her father. As she reached the platform before the altar, her dainty foot brushed a potted flower, upsetting it. She looked at the spilled dirt gravely, then raised her large childlike eyes to the sedate face of the old minister. "That's a hell of a place to put a lily."

"Did you hear what happened to my neighbor who was milking his cow when she was struck by lightning?"

"No. What happened?"

"He was left holding the bag."

Overhead on the 8:15: "And when my husband says he lives on greens he means a golf course."

An artist painting in the country had a farmer spectator.

"Ah," said the artist, "perhaps you, too, are a lover of the beauties of Nature. Have you seen the golden fingers of the dawn spreading across the eastern sky, the red-stained, sulphurous islets floating in the lake of fire in the west, ragged clouds at midnight, blotting out the shuddering moon?"

"Nope," said the farmer, "not lately. I've been on the wagon for over a year."

"Who," inquired the deaf old man of the minister, "was the stranger who took up the collection today?"

"That was our new deacon."

"New Dealer you say?"

"No; deacon. He is the son of a bishop."

"Yes, all of them are!"

"Where'd you get that black eye?"

"I was out with Bill's old girl."

"Yeh, but the black eye?"

"Bill's a liar!"

It happened during the rush for gasoline ration coupons, and the scene was an American high school. The white-haired teacher at the table looked up and grinned at the man standing before her, application in hand.

"Well," she said, "after all these years, I'm finally able to give you an 'A'!"

A small storekeeper, much to the astonishment of his neighbors, suddenly decorated his shop window with a gorgeous new blind. It was the sensation of the day, and few of his brethren failed to make some remark to him about it.

"Nice blind you've got there, Isaac," said one.

"Yes, Aaron."

"How much did it cost you, Isaac?"

"It didn't cost me anything, Aaron. My customers paid for it."

"What! Your customers paid for it?"

"Yes, Aaron. I put a little box on my counter, 'For the blind,' and they paid for it."

Dear Sirs:

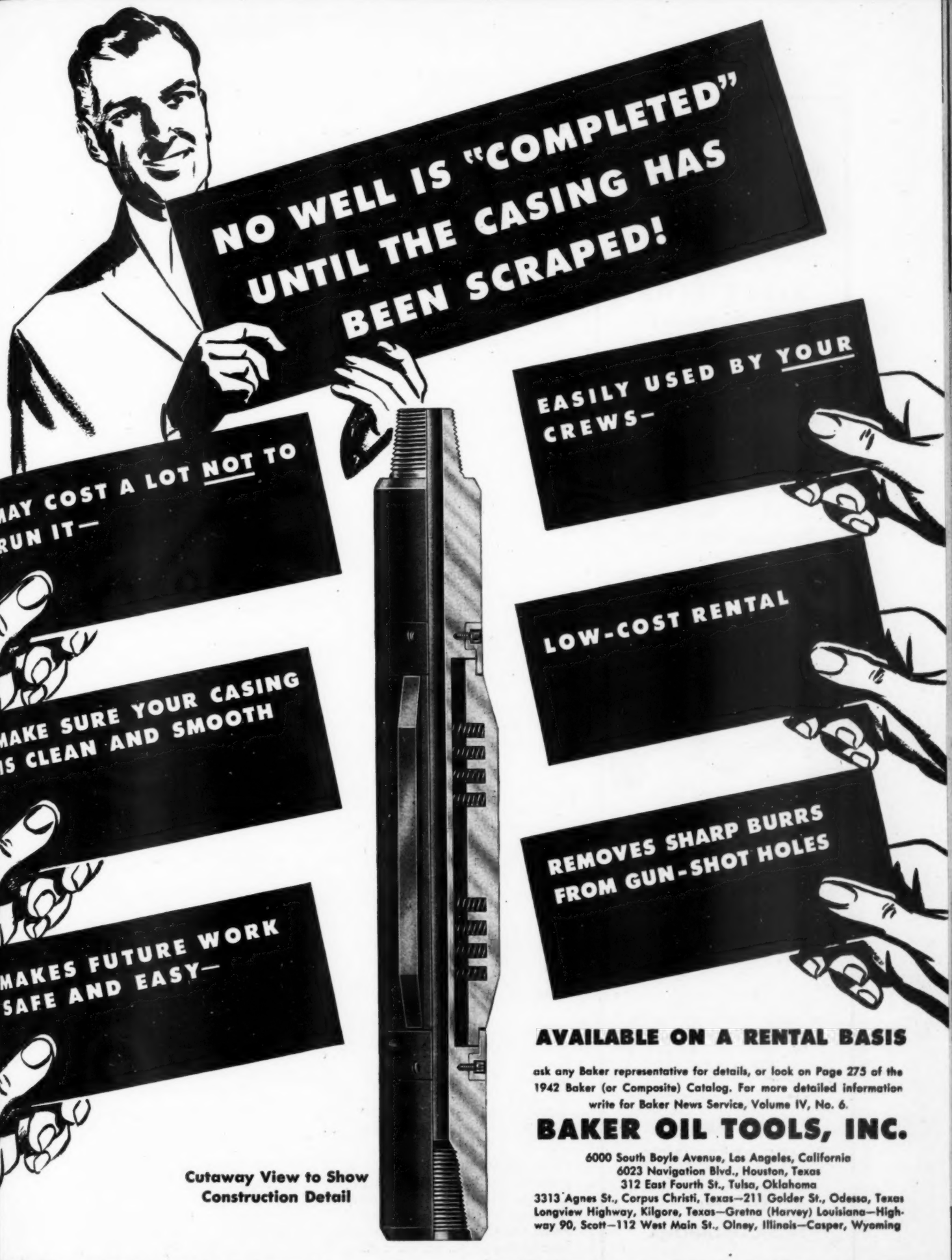
The answer to the engineering problem in your November issue should be very simple for any engineer with the usual practical experience.

The woodpecker will finish the job in 48 hours less than world record time without the use of any vitamin tablets until 24 hours after the premises are completed and occupied if the following clause be inserted in the contract by the architect:

"The contractor shall have free access without competition for a period of 30 days after the above structure shall be completed and occupied."—A.D.G.

"I never could understand why a fellow should not be allowed to have more than one wife."

"Well, after you are married you will realize that the law protects those who are incapable of protecting themselves."


NO WELL IS "COMPLETED" UNTIL THE CASING HAS BEEN SCRAPED!
MAY COST A LOT NOT TO RUN IT—
MAKE SURE YOUR CASING IS CLEAN AND SMOOTH
MAKES FUTURE WORK SAFE AND EASY—
EASILY USED BY YOUR CREWS—
LOW-COST RENTAL
REMOVES SHARP BURRS FROM GUN-SHOT HOLES

Cutaway View to Show Construction Detail

AVAILABLE ON A RENTAL BASIS

ask any Baker representative for details, or look on Page 275 of the 1942 Baker (or Composite) Catalog. For more detailed information write for Baker News Service, Volume IV, No. 6.

BAKER OIL TOOLS, INC.

6000 South Boyle Avenue, Los Angeles, California
6023 Navigation Blvd., Houston, Texas
312 East Fourth St., Tulsa, Oklahoma
3313 Agnes St., Corpus Christi, Texas—211 Golder St., Odessa, Texas
Longview Highway, Kilgore, Texas—Gretna (Harvey) Louisiana—Highway 90, Scott—112 West Main St., Olney, Illinois—Casper, Wyoming

ANOTHER *PRACTICAL* AND *DEPENDABLE* BAKER TOOL

BAKER ROTARY CASING SCRAPER

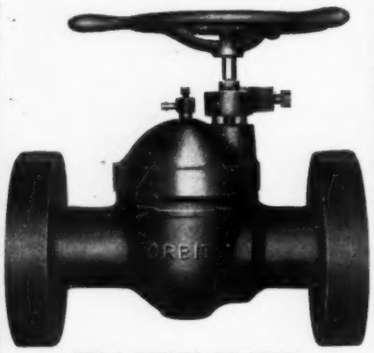
OIL WELL IMPROVEMENTS CO.

Pioneer creator and manufacturer of drilling and producing equipment, has been in the

FIRST LINE
of the Oil Industry's
Production Front

Now . . .

OWI products are serving in the
FIRST LINE
of the Navy's
Destruction Front



THE ORBIT GEARED MASTER VALVE

And while most of our production facilities are devoted to vital production for our fighting Navy, we will continue to furnish Orbit Valves to the Oil Industry to the limit of our ability.

If you have any questions regarding the care and maintenance of your Orbit Valves, write us.

OIL WELL IMPROVEMENTS CO.
Since 1912
TULSA, OKLAHOMA

Running Tour

WITH MEN IN THE INDUSTRY

C. P. PARSONS, vice president of Halliburton Oil Well Cementing Company, Duncan, Oklahoma, has accepted an appointment as assistant to FRANK WATTS, director of the Materials Division of Petroleum Administration for War, Washington, D. C. The appointment was effective January 1.

THOMAS A. TELFER, vice president and general manager of the Calumet Refining Company, Chicago, Illinois, passed away January 1.

FRED "PETE" WALLACE, after 15 years' service with the Link-Belt Company, recently resigned his connection with that organization. Lately he had been in charge of sales to the oil industry. Wallace is well known not only to the industry in this country but also abroad, having made two tours of South American fields. He is a member of the Houston chapter of Nomads. His present address is Park Lane Apartments, Houston, Texas.

EVERETT A. KERMOTT has been named general manager of the White Eagle division of Socony-Vacuum Oil Company, succeeding L. L. Marcel, retired.

GEORGE MURRAY WELLING, 55, secretary-treasurer of E. H. Moore, Inc., died in Tulsa, Oklahoma, December 28.

C. W. KRAUSE, head of the land and exploration department at Houston, Texas, for the Ohio Oil Company, has been transferred to Tampa, Florida. Krause was named manager of the new southeastern division and will direct the Ohio company's activities in Mississippi, Florida, Alabama, and Georgia.

WILLIAM G. SKELLY, president of Skelly Oil Company, Tulsa, Oklahoma, was elected and JOHN R. SUMAN, vice president, Humble Oil and Refining Company, Houston, Texas, was re-elected to the board of directors of the National Association of Manufacturers.

H. A. EKLUND, head of the land department, and Robert E. Kepke, executive assistant, have been named vice presidents of the British American Oil Producing Company and Toronto Pipe Line Company. Kepke will manage the pipe line.

JOHN C. KOCK has been transferred from the home office of the Brown Instrument Company in Philadelphia, Pennsylvania, a division of Minneapolis-Honeywell Regulator Company, to the New York office of both companies. He will represent both Minneapolis-Honeywell and Brown accounts in the petroleum industry as field sales engineer. He served in a similar capacity for the Brown organization while in Philadelphia.

I. S. SALNIKOV is now associated with M. L. Haider and the Standard Oil Development Company with offices at 30 Rockefeller Plaza, New York. M. A. WRIGHT will replace Salnikov as chief engineer of The Carter Oil Company. Wright will handle this assignment in addition to his present duties as assistant to J. R. McWilliams, production manager.

STUART BUCKLEY, head of the production research department, Humble Oil and Refining Company, presented an illustrated lecture recently on "The Development and Control of Oil Reservoirs" before the student section of the A. I. M. E., University of Texas.

HICKS ELLINGTON THOMPSON, 57, died in Dallas, Texas, December 14 after a heart stroke. He had been associated with Magnolia Petroleum Company since 1918 where his last title was that of assistant superintendent of the right-of-way and claims department.

R. E. SMITH purchased all the oil production of Smith and Hammill, prominent independent company, from the junior member of the firm for a cash consideration of $1,500,000. Royalties, oil payments, or fee lands were not included in the deal. Drilling equipment was divided. CLAUD B. HAMMILL, the junior partner, said he would remain in the oil business.

PHIL H. BOHART, assistant to the vice president of the Gulf Oil Corporation and the Gulf Pipe Line Company, was elected president of the Tulsa chamber of commerce for 1944.

S. F. SHAW, consulting engineer, until recently acting as associate professor at A. and M. College of Texas, is temporarily stationed in Calgary, Canada.

Built to set the pace

and HOLD IT!

After more than a decade of service in all types of heavy-duty oil field equipment on the kind of drilling, pumping and power generating jobs that really put power "through the wringer" — this fact about Cummins Dependable Diesels stands out like an unbroken window in Berlin: They are built to set the pace in dependability, economy and speed — and hold it! Day and night... until the job is wrapped up and delivered.

CUMMINS ENGINE COMPANY

Columbus, Indiana

MACHINERY and EQUIPMENT

Gun Perforator, Tester

BY combining a gun perforator and production tester into one unit, which perforates the casing and gives an accurate gauge of the productiveness of a zone on a single run into the well, McCullough Tool Company is enabled to offer a new time-and-money-saving service to the oil industry. The gun casing tester is run on drill pipe or tubing, and accurate pipe measurements are utilized to assure the location of the perforations in the exact zone designated for testing.

The gun tester consists of a production tester with a gun perforator attached below it. The gun perforator may be a short unit for firing one to four shots, or it may be a standard gun that shoots 10, 20, or 30 shots in a 5 ft. section. A number of guns may be joined together to cover the extent of the zone to be tested.

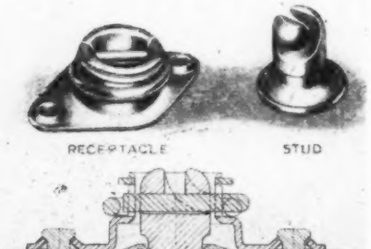
Operation of the gun tester is both quick and easy. When the gun tester is stationed at the zone to be tested the gun is fired and the control head or Christmas tree attached to the production string. The tester is then raised and set above the perforated area and the sample-taking valve is opened. Setting the tester isolates the zone being tested from the hydrostatic pressure so that the test is made under formation pressure only and before the zone can be contaminated by the well fluid. This insures an accurate gauge of the productiveness of the zone. When a number of zones are to be tested, the uppermost zone is tested first and the others in succession, working downward. Thus, no plugs or squeeze jobs are required between tests and much time and expense are saved.

In addition to its use in testing for oil production, the gun tester is widely used in testing for water shut-off and in determining the success of squeeze cementing operations. The tool may be run with or without a water cushion, and, due to its design, it releases easily after the test, whether wet or dry. Further information may be obtained from McCullough Tool Company, 5820 South Alameda Street, Los Angeles, California.

New Fastener

W. T. HEDLUND, president of Elastic Stop Nut Corporation of America, Union, New Jersey, announces that his organization has acquired world rights to a new fastener that will add to the scope of his company's work in present war production as well as in postwar commercial use. The new fastener is a spring-lock device invented by Dr. E. L. Mack, and perfected by the Aircraft Parts Development Corporation, Summit, New Jersey, under the direction of D. C. Hungerford.

The new fastener is a lightweight unit of extremely rugged construction and is particularly suitable for holding the engine cowlings of high speed war planes. The army air forces have tested it at Wright Field and have found that it meets specifications for use in any army airplane. Also, after complete testing, the Navy Bureau of Aeronautics has found that it meets navy specifications for aircraft of that branch of the service.



CROSS SECTION SHOWING ASSEMBLY IN LOCKED POSITION

In addition to its important use on airplanes, this fastener is suited to many postwar commercial applications, such as access plates on farm machinery, panels on motor trucks, home heating units, radio equipment, and at any point where a quick-acting vibration-proof non-rattling fastening is needed.

Production tooling is in the final stages, and shipments will begin in the latter part of January. Hedlund states that technical data covering tests, approvals, and available sizes, are now available.

The addition of this fastener to the Elastic Stop Nut Corporation's production further enhances ESNA's position in supplying high grade fastenings of all types as part of its postwar planning committee's program for being in a position to supply special fastenings that will be required for the heavy postwar production of home appliances, automobiles, rail and bus lines, and other commercial uses.

"Trigger Finger" Guard

A COMPARATIVELY new occupational hazard that is causing absenteeism is described as "women welders' disease" or more commonly known as "trigger finger." It is believed to be most common among women employees because their hands are comparatively tender and smaller in size than men's hands.

Tendons become bruised and begin to swell on the hand that grasps the stinger or torch, with the result that one or more fingers become stiff, and relatively useless. In the majority of cases the resulting disability runs from three weeks to three months; whereas in severe, neglected cases surgery may be necessary to relieve the condition.

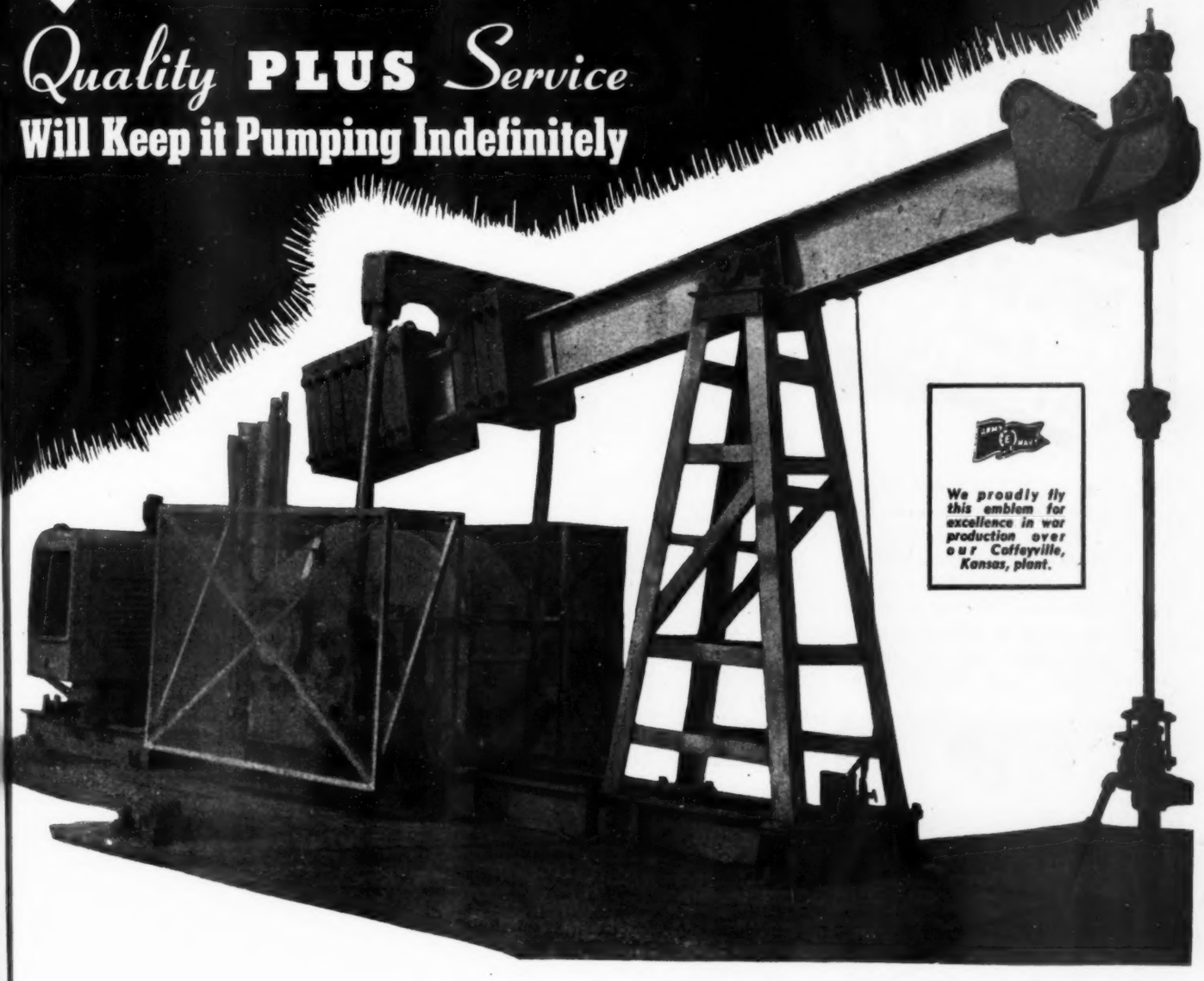
A "trigger finger" guard has been developed by E. D. Bullard Company, industrial safety supply manufacturer, that is said by users to prevent this condition. This device consists of a chrome leather palm and finger guard to be worn under welders' gloves. Three soft spongy cleats are so placed on the guard that they protect the parts of the hands that are known to be vulnerable.

Either right or left hand guards are available. Adjustable wrist strap holds the guard in the correct position, and also makes the "trigger finger" guard a universal fit for all women.

Additional details may be had from E. D. Bullard Company, 275 Eighth Street, San Francisco 3, California.

QUALITY BUILT THIS PUMPER

Quality PLUS *Service*
Will Keep it Pumping Indefinitely



Parkersburg pumpers are backed by 47 years experience in building the finest oil field equipment that quality materials, quality workmanship and intelligent engineering can produce. They're the kind of pumpers you need for today's vital job of meeting your share of the industry's all out producing program.

Parkersburg pumpers are also backed by a service organization that covers every active field in the country. No matter where you are there's a Parkersburg representative near you who makes it his business to see that they deliver the fine performance you expect of them. And today, this can mean plenty to you.

For a complete review of the Parkersburg line of geared and OCS Chain units, see your Composite Catalog.

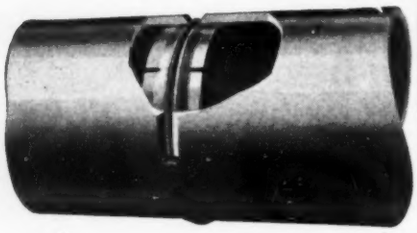
THE PARKERSBURG RIG & REEL COMPANY
PARKERSBURG, W. VA.
General Sales Office: Coffeyville, Kan.
Dallas Houston Tulsa Los Angeles New York

THE PARKERSBURG RIG AND REEL CO.

PARKERSBURG

Weld Pipe
FASTER
and BETTER
with
WEDGE
Split
CHILL RINGS

The reason WEDGE Chill Rings are so efficient for welding pipe is because of the patented SPLIT Feature. This makes them different than ordinary rings. They are FLEXIBLE and will adjust themselves TIGHTLY to the irregular diameter of unfinished inside surfaces of pipe. You are assured STRONG joints because WEDGE Chill



Rings enable penetration to the inside of pipe with the first layer of weld metal. In fact, the joint is the STRONGEST part of the line. In case of shock or strain the pipe will fail before the reinforced joints. Remember, you can weld a line FASTER and BETTER with WEDGE Split Chill Rings. It will pay to investigate.

Write for Information

WEDGE PROTECTORS, INC.
9522 Richmond Avenue Cleveland 5, Ohio

WEDGE
Split CHILL RINGS
SAVE MONEY

Molecule Sorter

MODERN refineries and chemical plants require accurate control of all materials and processes. Many products are made continuously—thus, if an error creeps in, thousands of gallons or hundreds of tons of material will be spoiled if correction is not made speedily. If the product happens to be high octane aviation gasoline or synthetic rubber constituents, the error becomes almost a national calamity.

Production of high octane gasoline, butadiene, or styrene involves precise critical processes. Laboratory accurate on a huge scale, they need controls that are both exact and rapid. Westinghouse Research Laboratory has developed a new control mechanism that fulfills the

Dr. John A. Hipple, who developed the instrument, is shown with the key part of the equipment

requirements. Previously, chemical tests in an oil refinery have been laborious and have required hours to complete. The new device thoroughly checks operation in a matter of minutes—and requires only one or two technicians.

The mass spectrometer has long been used in laboratories, particularly for exploring the field of nuclear physics. It determines both qualitatively and quantitatively the constituents of a gas. With substances that are alike chemically and differ only slightly in weight, chemical analyses are extremely difficult. The mass spectrometer uses only a small quantity of the gas — it need be only a thimbleful—and ionizes it by impact of electrons from a hot filament in an evacuated tube. The stream of charged molecules is drawn along the tube into a strong magnetic field, where it is bent into an arc-shaped path. The heavier the ion, the larger the radius of curvature of its path. As a result, different molecules emerge from the field at various locations, but all of the same kind leave at one particular spot. Different charged molecules are collected successively at an exit slit into a current that can be amplified and measured. In this way, constituents of any gas can be determined regarding kind and proportion.

Built for use in refineries, chemical plants, and similar locations the mass spectrometer is a self-contained tool. No power supply other than 110 volts, 60 cycles is required. The instrument is extremely sensitive and can measure ion beams as small as one billionth of one microampere. (Average antenna current for the home radio is at least one microampere.) In other words, the mass spectrometer counts as few as 6000 ions per second, which isn't many considering that about three billion billion electrons surge in and out of a 60 watt lamp each second. The device can readily detect, for example, the presence of one part of oxygen in 10,000 parts of nitrogen.

The mass spectrometer is expected to have many industrial uses. It may serve to check gases in protective-atmosphere furnaces, it may check completeness of evacuation processes, or it may detect presence of some undesirable constituent in process gas.

Thermometer

A NEW thermometer is announced by the American Schaeffer and Budenberg Instrument Division of Manning, Maxwell and Moore, Inc., Bridgeport, Connecticut. Originally designed as a means of conserving the critical copper used in cast-bronze cases, it has grown into a tremendous forward advancement in the manufacture of industrial thermometers, according to the makers. The following new features have been added, the manufacturer says:

It has been entirely redesigned by one of the country's foremost industrial designers.

It incorporates all major design improvements that had been accumulated over the years.

It has been made so that it is possible to supply back, side, and oblique angles without using the ball joint.

The scales and tubes are placed in a manner which produces greatest readability.

A new method of making the scale has been developed that produces a more legible and better looking scale.

The case has been reinforced to give it all the structural stiffness of a plate girder.

The screw that holds the cover has been attached so it can never come loose and be lost.

The case is practically corrosion-proof. In actual tests the black suede finish showed no corrosion after 100 hours in salt spray.

The scale is black with yellow figures. The tube is red-reading mercury.

Smith Heads Department

The retirement of M. J. McLaughlin as vice president and manager of production, Magnolia Petroleum Company,

E. D. SMITH M. J. McLAUGHLIN

on January 1, 1944, was announced by D. A. Little, president.

The election of E. D. Smith, who since July, 1939, has been assistant manager, as vice president and manager of production and a director of Magnolia Petroleum Company, succeeding McLaughlin, was also announced.

A. E. Chester has been transferred to the Dallas office as assistant general manager of the production department.

J. F. Conley succeeds Chester as division superintendent, Illinois and Kentucky. Russell Clymer succeeds Conley as district superintendent, Chase, Kansas, district.

Trout Reelected

At its annual meeting in New York the National Association of Manufacpany, Lufkin, Texas, peace-time manuLufkin Foundry and Machine Comvice president. Trout is president of turers reelected W. C. Trout regional facturers of oil well pumping units, now engaged in production of war goods.

Trout has been prominently engaged in the activities of the national and state manufacturers associations, having served as president of the state association for three successive terms, one year as chairman of the board, and is now serving as chairman of the executive committee.

Wins Gold Star

Continued record production of pumps for Liberty cargo ships and tankers has won added recognition from the United States Maritime Commission for the men and women of the Wilson-Snyder Manufacturing Division of Oil Well Supply Company.

Admiral H. L. Vickery, commissioner, praised the war work of the employees in this U. S. Steel plant, situated at Braddock, Pennsylvania, in a letter notifying them that a second gold star is to be added to the Maritime "M" pennant awarded the company last year for outstanding production achievements.

WAR IS THE MAIN JOB NOW!
The main job — and a tough one! But War adds "experience under pressure" to our half-century of peacetime progress, so that Spang Cable Tools in the year A.V. (After Victory) will be even better than ever. Although scarce now, they'll then be plentiful enough to fill all your requirements.
SPANG AND COMPANY
Butler, Pennsylvania
SPANG
THE HIGHER STANDARD
The Biggest Name in
CABLE TOOLS

Company Official Dies

Walter H. Parker, vice president in charge of manufacturing, Pittsburgh Equitable Meter Company, died December 28 at his home in Pittsburgh, Pennsylvania, from a heart attack following the contraction of pneumonia. He was 51 years old.

W. H. PARKER

Parker was a graduate of North Carolina State College of Agriculture and Engineering at Raleigh, North Carolina. Prior to becoming associated with the Pittsburgh firm, in 1929, he was chief engineer for the Fry Equipment Company of Rochester, Pennsylvania. During the first world war he served as a captain in the air corps and was honored with a citation for the development of a synchronizing principle for firing bullets between the blades of airplane propellers. During the present war Parker contributed many valuable innovations in the development and manufacture of medium caliber armor-piercing shot.

Join Girdler Staff

Gas Processes Division of the Girdler Corporation, Louisville, Kentucky, announces that Leon E. Osmer and Melvin H. McKinney, engineers, have recently joined the organization. Osmer has been with the Semet Solvay Engineering Corporation since 1924. McKinney has been with Lago Oil and Transport Company, spending much of the time since 1930 in Aruba. Since America's entry into the war he has been with Dow Chemical Company and Sinclair Rubber Company.

Receives Second Award

The Army-Navy production award has been presented the second time to the Lufkin Foundry and Machine Company, Lufkin, Texas. The award consists of a white star, which is added to the original pennant and is evidence of approval on the part of the War Department of continued high standard of production and a symbol of appreciation for such achievement.

The Lufkin company, peace-time manufacturers of reduction gear oil well pumping units, are engaged in the manufacture of howitzer gun carriages, General Sherman tanks, gears, 1000-hp. ship propulsion gears, turbo electric gear generators, practice bombs, and truck trailers.

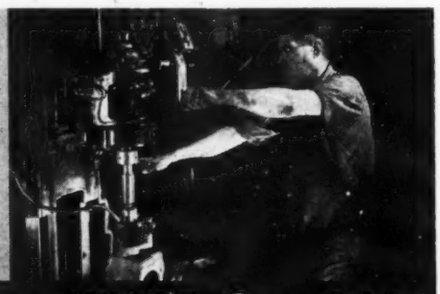
W. C. Trout is president and general manager of the Lufkin Foundry and Machine Company.

New Advertising Manager

Tube Turns and the Girdler Corporation, Louisville, Kentucky, announce the appointment of Gene Wedereit as advertising manager. Formerly vice president and director of creative service with the E. F. Schmidt Company, Milwaukee, Wisconsin, Wedereit went to Louisville recently as a result of his work in the designing and production of Tube Turns' 240 page catalog. Walter Girdler, Jr., formerly advertising manager, is now director of personnel.

GENE WEDEREIT

MIRROR-FINISH CYLINDER HONING



is a Production MUST for ALL WISCONSIN ENGINES

Yes . . . even the little Model AA 1 hp., single-cylinder Wisconsin Air-Cooled Engine has its 2¼"-bore cylinder honed to a high mirror finish . . . to assure smooth, full-power operation and maximum fuel and maintenance economy.

No "hidden detail" of design and construction is neglected or sacrificed to "price expediency" in the manufacture of these fine engines. These details are important to YOU in the operation of *your equipment*. Wisconsin air-cooled engine power is the answer.

Most H.P. per pound

WISCONSIN MOTOR Corporation

MILWAUKEE 14, WISCONSIN, U. S. A.

World's Largest Builders of Heavy-Duty Air-Cooled Engines

WRITE TO HARLEY SALES CO.

510 ATLAS BLDG., TULSA, OKLA.
B & M BLDG., HOUSTON, TEXAS

OIL FIELD DISTRIBUTOR FOR WISCONSIN ENGINES AND ALL TYPES OF UTILITY UNITS

$100 REWARD

Turn to Page 275 in the 1942 Composite Catalog and read all about the Baker Rotary CASING Scraper and how it removes cement sheaths, burrs and warts from the inside of your casing. Read how it smooths up the casing so that packers and swabs won't be damaged in the future. Read how simple it is for your crews to run—how no serviceman is needed—and then call up the nearest Baker office and find out how low the rental cost is. If you cannot find a picture of the Baker Rotary CASING Scraper on Page 275, then we will pay you $100 reward.

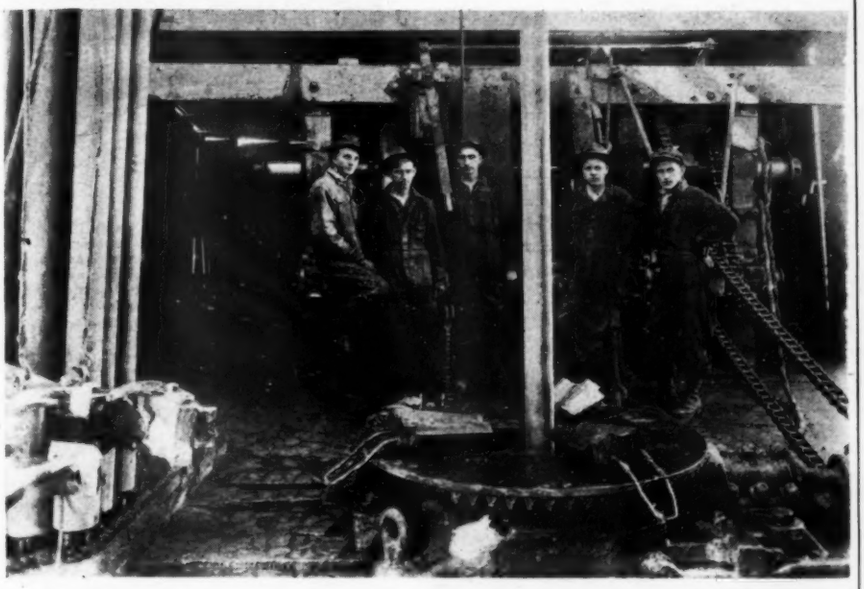
BAKER

ROTARY CASING SCRAPER

BAKER OIL TOOLS, INC.

(The address you will want is on Page 226.)

Elmer Decker 25 Years in the Oil Industry



The handsome young man resting gracefully on the brake at the extreme left in the accompanying photograph is Elmer L. Decker of Martin-Decker fame. This picture, taken in 1922, shows "Deck" shortly after starting in the oil business 25 years ago, his first job being with the Standard Oil Company of California at Taft, California. After drilling in California, Texas, and Oklahoma in 1927-28, he joined with W. R. (Frosty) Martin to form the Martin-Decker Corporation of Long Beach, California. Since that time Deck has become widely known in the oil fields throughout the United States and in foreign countries. It was largely through his efforts that the Nomads was founded in 1938 and eventually expanded to the national organization it is today. He was first president of what is now the Los Angeles chapter and first chairman of the National Board of Regents of the Nomads.

Others in the photograph are D. Hensley, second from left; Fred Blaswick, deceased; Victor Young, now toolpusher for International Petroleum in Peru, and W. Burton.

East Texas Section A.I.M.E. Officers

New officers were elected for the East Texas Section of the American Institute of Mining and Metallurgical Engineers, December 20, 1943, at Kilgore, Texas. The five officers present at the meeting in the above photograph are, left to right: D. W. Akins, Jr., Ohio Oil Company, Shreveport, Louisiana, board of directors; R. W. (Woody) Erwin, Salt Water Control, Inc., past chairman of the section, board of directors; C. E. Mangold, Dowell Incorporated, Kilgore, vice chairman; John Bell, Humble Oil and Refining Company, Tyler, chairman; W. S. Morris, East Texas Salt Water Disposal Company, chairman of the Petroleum Division of A.I.M.E., Kilgore, and R. M. Hess, Shell Oil Company, Kilgore, reelected secretary-treasurer. Other officers elected, but not present at the meeting are T. S. Bacon, Lone Star Gas Company, Dallas, vice chairman, and C. B. Carpenter, U. S. Bureau of Mines, Dallas, board of directors.

LUFKIN

"ANCHOR" CHROME CLAD STEEL TAPE — THE OILMAN'S CHOICE

ONE HALF INCH LINE

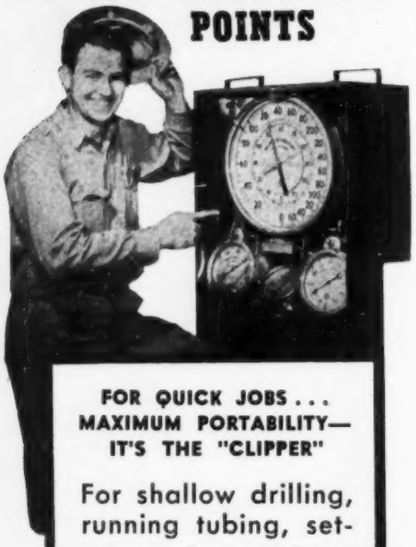
A sturdy, finely-built tape that every busy oilman will want to carry. Jet black markings on the satin chrome finish are easy to read—even in poor light. Surface won't rust, crack, chip or peel. Genuine leather case. Folding flush handle is opened by a push pin. See the "Anchor" at your supply house and write for catalog.

LUFKIN

SAGINAW, MICHIGAN • New York City

TAPES - RULES - PRECISION TOOLS

WEIGHT INDICATOR POINTS



FOR QUICK JOBS . . . MAXIMUM PORTABILITY— IT'S THE "CLIPPER"

For shallow drilling, running tubing, setting packers and liners, fishing—wherever minimum rig-up time and maximum portability are essential, the Martin-Decker "CLIPPER" Tool Pusher Type Weight Indicator is the instrument for the job. It combines in one compact, streamlined unit complete accuracy, portability and adaptability for all drilling and production operations not requiring a chart record. Off and on the dead line in an instant, the Clipper is easily transported from rig to rig and can be used in any spot at any time . . . eliminating haphazard guesswork or estimations.

Easy to Read
Extremely Accurate
Completely Self-Contained

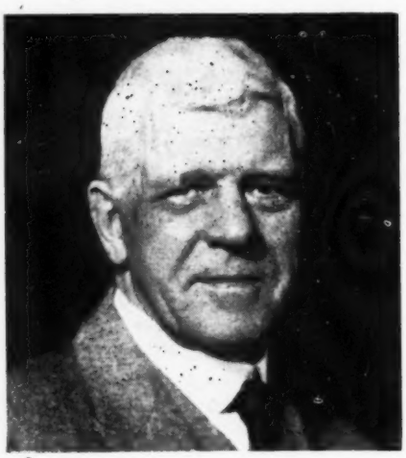
MARTIN-DECKER CORP.
LONG BEACH, CALIFORNIA
A. F. McQUISTON, BAKERSFIELD, CALIFORNIA
REED ROLLER BIT CO., HOUSTON, TEXAS

Moves N.Y.C. Office

Kerotest Manufacturing has removed its New York City office to Room 3206 Lincoln Building, 60 East 42nd Street. The telephone numbers are MUrrayhill 2-4816-7, and the postal district New York City 17. The Kerotest home offices and plants are at Pittsburgh, Pennsylvania.

Death Claims W. G. Irwin

William G. Irwin, nationally prominent industrialist, financier and philanthropist, and one of the key figures in the development of this country's diesel engine industry, died recently in Indianapolis. Death, attributed to heart failure, occurred in the offices at the Indiana National Bank of which Irwin was president. He was 77 years old.



WILLIAM G. IRWIN

The story of Irwin's part in the development of the high speed diesel engine had its beginning a quarter of a century ago and it forms an interesting chapter in a remarkable career that included participation in many industrial, financial, political, educational, religious, and philanthropic activities from coast to coast.

During the last war, in 1918, Irwin had in his employ, as a chauffeur, a young man whose ambition it was to develop a high speed diesel engine suitable for trucks, buses, small boats, and other types of mobile equipment too small to accommodate the heavy, cumbersome diesel engines of that day. Always interested in any new developments that promised the advancement of industry, Irwin became convinced of the soundness of the young man's ideas and gave freely of his encouragement and financial backing.

The young man's name was Clessie L. Cummins and out of his early association with Irwin grew the Cummins Engine Company, which Cummins today heads as president, and the Cummins Diesel Engine, which pioneered the use of diesel power in highway transportation and many other industries.

GET ACCURATE RESULTS
Quickly . . Easily . . with
CURTIN CENTRIFUGES

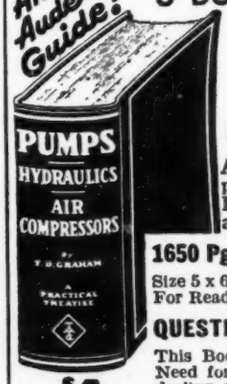
You can maintain your required speed for the period of the test with much less effort. Curtin centrifuges, proven world-wide, are heavy duty, rigidly constructed, and extremely simple in design. Illustrated bulletin, giving full details, available upon request.

W·H·CURTIN & CO. Inc.
HOUSTON U·S·A TEXAS

Free Examination

PUMPS

An Audel Guide! **3 Books in One!**



Now Ready—
AUDELS PUMPS
HYDRAULICS
AIR COMPRESSORS

A New Modern-Comprehensive Guide for Engineers, Pump Operators and Mechanics.

1650 Pgs., 1654 Illustrations

Size 5 x 6¾ x 1¾—Fully Indexed For Ready Reference including

QUESTIONS AND ANSWERS

This Book Covers a Long Felt Need for One Inclusive Volume dealing with the whole field of modern Pumps, Hydraulics, Air Compressors and the many lines that tie in. Easy to understand.

To get this assistance for yourself, simply fill in and mail *FREE COUPON* today.

$4 COMPLETE
PAY ONLY $1 A MO.

AUDEL, Publishers, 49 W. 23 St., New York 10
MAIL AUDELS PUMPS, HYDRAULICS, AIR COMPRESSORS (Price $4) on 7 days free trial. If O.K., I will remit $1 in 7 days and $1 monthly until the $4 is paid. Otherwise I will return it.

Name_____
Address_____
Occupation_____
Employed by_____

P.E.N.

Homco Opens Branch

Houston Oil Field Material Company, Inc., has opened a branch store at 1504 North Mill Street, Jackson, Mississippi. Joe C. Seale is store manager, having been transferred from Victoria, Texas. Tom F. Burke is division manager, with headquarters in New Orleans, Louisiana.

T. F. BURKE

Homco has also recently opened new branches at Raymondville, Willacy County, Texas, and Kenedy, Karnes County, Texas.

J. C. SEALE

Complete stocks of oil well supplies, as well as drilling muds and chemicals, are carried, and each store may be contacted for Homco cutting and fishing tool service.

Management Changes

Ralph C. Harden, vice president of Gustin-Bacon Manufacturing Company, has assumed direction of all sales activities of the company, making his headquarters in Kansas City and New York City.

J. F. Stephens, vice president, is in charge of product development and research, and J. O. Brelsford, general manager of production, is in charge of manufacturing. Stephens and Brelsford have their headquarters in Kansas City.

Van Petten to New Post

Appointment of H. E. Van Petten as manager of the B. F. Goodrich advertising division is announced by Frank T. Tucker, advertising director of the pioneer Akron rubber concern. In his new capacity Van Petten will have charge of tire advertising, which has been under the direction of George F. Cozzens, who has joined the army, as well as the advertising of the firm's industrial products and Koroseal. Van Petten has been in the rubber industry for 16 years, all of that time in the advertising field, and has made his headquarters in Akron the last 14 years.

H. E. VAN PETTEN

WHEN IT'S TOO HOT FOR ORDINARY PIPE

use INSIDLINE

Insidline is an internal insulation and lining to hold the temperature of pressure piping to 650° F., or below, where the phenomenon of "creep" does not occur and metals can be operated indefinitely at usual stress allowances. Thus the use of carbon steel piping, normally specified for a given pressure, is made possible for a wide range of internal temperatures.

At the same time Insidline accomplishes the secondary objective of heat conservation. This can be carried to any degree indicated by the economies or other considerations in a given process.

Because Insidline greatly simplifies the design of pressure piping, and permits the use of ordinary carbon steel piping instead of special, costly, alloy steel, substantial savings result. If you have a hot pipe problem in any diameter from 2" to over 100", it will pay you to check with B-H engineers.

Baldwin-Hill Co., 563 Klagg Ave., Trenton 2, N. J. Plants in Trenton, N. J., Kalamazoo, Mich., and Huntington, Ind.

Baldwin-Hill

BH COMPANY

HEAT & COLD INSULATIONS

Simplicity of Design Means Easier Maintenance

SERVICING IN THE LINE SAVES TIME . . . . . .

. . . and it saves the valve, too, because regular servicing not only keeps the valve in top condition and gives it longer life, but it reduces the possibility of having to make extensive repairs later. The simplicity of Lunkenheimer design makes all parts accessible for checking any first signs of lagging operation, and the taking of precautionary steps.

Valves are among your most vital production equipment . . . in fact, the very backbone of your production lines. That's why new valves are scarce and hard to get. That's why it's not only good business, but imperative business, to take the best of care of the valves you now have in service.

It's not a difficult job. Valves respond to good treatment and the little time required to keep them in top condition will be well repaid in uninterrupted production.

Use the complete facilities of Lunkenheimer distributors.

IT'S EASY . . . TO GET TO THE WORKING PARTS

Simply open the valve part way, unscrew union ring, and the complete assembly of working parts can be lifted from the body—for inspection, cleaning, seat and disc regrinding, or replacement of parts if necessary.

ESTABLISHED 1862
THE LUNKENHEIMER CO.
"QUALITY"
CINCINNATI 14, OHIO, U. S. A.
NEW YORK 13 CHICAGO 6
BOSTON 10 PHILADELPHIA 7
EXPORT DEPT., 318-322 HUDSON ST., NEW YORK 13, N.Y.

LUNKENHEIMER VALVES

Open Pittsburgh Office

Establishment of new offices in Pittsburgh, which opened January 3, is announced by The McCarty Company, industrial advertising counsellors.

R. S. REED, JR.

R. S. Reed, Jr., for the last 12 years advertising director of Pittsburgh Equitable Meter Company of Pittsburgh, and Merco Nordstrom Valve Company of Pittsburgh and Oakland, has been appointed manager of the Pittsburgh office. The McCarty Company has handled the advertising of the Nordstrom concern for 22 years through its Los Angeles and San Francisco offices.

Beginning January 3 the Pittsburgh Equitable Meter account is also to be serviced by the company's Pittsburgh office, which is in Suite 2205, Koppers Building.

Schlumberger Promotes

Schlumberger Well Surveying Corporation, Houston, Texas, announces the promotion of R. R. Rieke from district manager in Wharton to division manager of the Texas Gulf Coast division in Houston. He will replace George H. Murray, who is on sick leave.

R. R. RIEKE

Young Representative

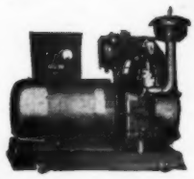
Young Radiator Company, manufacturers of heat transfer products, announces the appointment of the W. P. Nevins Company as sales and engineering representatives in the Chicago territory.

The W. P. Nevins Company will provide a complete sales and engineering service on the line of Young heat transfer products including unit heaters, coils, air conditioning units, engine jacket water coolers, heat exchangers, Quad (radiator type) coolers and condensers, and evaporative type cooling units.

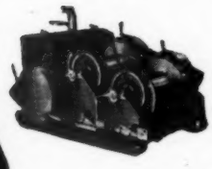
The engineering associates of Nevins, who will work with him in the territory, are C. L. Carlson and F. L. Winkler.

LEADING CONTRACTORS PREFER
Sterling
PUMPS • HOISTS • LIGHT PLANTS

DEPENDABLE
RUGGED
SIMPLE
•
SAVE
MONEY
SAVE
TIME



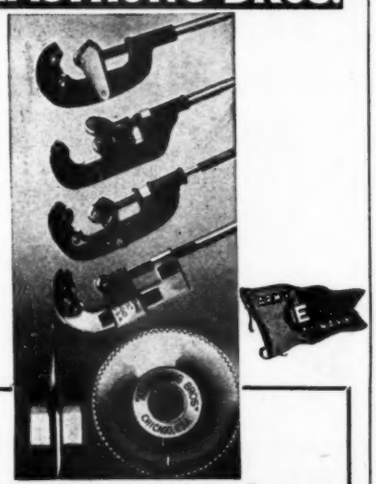
EASY
TO
OPERATE
•
WRITE
FOR
CATALOG



STERLING QUALITY

STERLING
MACHINERY CORPORATION
405-13 SOUTHWEST BLVD. KANSAS CITY 10, MO.

Look for the Arm-and-Hammer
ARMSTRONG BROS.



All ARMSTRONG BROS. Pipe Cutters are made in all standard types. Each is a quality tool with hardened steel pins and rollers. "Saunder Type"—hardened end of thrust rod bears on inserted hard steel block (double life). In "Drop Forged" and "Combination" types, which take either 1 or 3 wheels, a replaceable hardened steel nut takes up thrust. In the "Barnes" type thrust rod threads through drop forged steel section.

ARMSTRONG BROS. Knife Blade Cutter Wheels (smooth or knurled) have thin penetrating edges that hold their keenness because they are machines from special vanadium tool steel, hardened and oil tempered. Fit all standard-make pipe cutters.

Write for Catalog C-39a

ARMSTRONG BROS. TOOL CO.
"The Tool Holder People"
313 N. FRANCISCO AVE. CHICAGO, U.S.A.
Eastern Warehouse & Sales: 199 Lafayette St., New York

Sales Office Personnel

The personnel of The Dow Chemical Company's new Philadelphia and New England sales offices, which opened January 3, has been announced by Clayton S. Shoemaker, recently appointed eastern sales manager.

Alexander Leith, Jr., who has been with Dow's New York sales office since 1923, will head the Philadelphia office

A. LEITH, JR.

A. A. LAWRENCE

at 1400 South Penn Square, and Alfred A. Lawrence, native New Englander, who has been with Dow since 1940, has been selected as manager of the New England sales office at 20 Providence Street, Boston.

Other members of Dow's Philadelphia office are Frank H. Sellars, III, magnesium sales; Elmer K. Stilbert, plastics engineering, and Charles E. Seel, heavy chemicals and pharmaceutical sales.

Other men at the New England office are Felix J. DeSantis of Boston, heavy chemicals and pharmaceuticals; George B. Makepeace, plastics engineering, and Bradfore Durfee.

Trail Back in Oil Industry

James A. Trail, who formerly represented the Hyatt Bearings Division of General Motors Corporation in the oil industry, is again located in Dallas, Texas, and will represent the company from there. During the last year he has traveled out of Chicago and Detroit where he handled special assignments for Hyatt in connection with the war effort.

Crane Promotes Dwyer

Effective January 1, James A. Dwyer has been appointed general manager of sales and branches of Crane Company with headquarters in Chicago, Illinois.

Dwyer joined the Crane organization in 1917 at the Philadelphia branch. He has been successively estimator, salesman, chief clerk, branch sales manager, assistant branch manager, branch manager, and district manager. About a year ago he was made manager of branch houses, which responsibilities he will continue to assume in addition to his new duties as general manager of sales.

The Great Wall of China
Built About 3000 B.C.

BUILT TO LAST
A LONG LONG TIME

The founders of the Layne Organization realized the tremendous importance of water as a health, safety and industrial necessity. They pledged themselves never to sacrifice quality in the manufacture of Layne Pumps and Well Water Systems. That pledge, to the ever grateful thanks of thousands of Layne Well Water System owners, has been faithfully kept.

Today as always, Layne Pumps and Well Water Systems are still being made of the very finest quality materials. They possess highly important and exclusive features of construction which measureably lengthen their long life. And in addition, they embody outstanding and thoroughly proven engineering ideas that guarantee highest efficiency.

Wherever modern well water producing equipment is used—whether in the United States or in foreign lands, that which bears the name of Layne is definitely recognized as the world's standard by which all other makes are judged.

If your postwar plans call for the use of more water, Layne engineers will gladly cooperate in providing sound recommendations. For literature address LAYNE & BOWLER, INC., General Offices, Memphis 8, Tenn.

AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Texas Co., Houston, Texas ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Western Co. of Minnesota, Minneapolis, Minn. ★ International Water Supply Ltd., London, Ontario, Canada

LAYNE
WELL WATER SYSTEMS
DEEP WELL PUMPS

Builders of Well Water Systems for every Municipal and Industrial Need

STOODY 6
Applied by Welding Reclaims Worn Valves

NOW worn valves, valve parts and pump sleeves can be reconditioned to outperform new factory parts by a simple oxyacetylene welding application using Stoody 6. This new Stoody alloy, composed principally of cobalt, chromium and tungsten, will not oxidize—even under intense heat, has high impact strength in relation to its hardness, offers excellent resistance to abrasive wear, and is perhaps the easiest of all hard-facing alloys to apply. Stoody 6 is highly efficient for hard-facing new or old internal combustion exhaust valves, gate, globe and angle valves, hot oil pump sleeves, etc.

Trial order of 10 lbs. of 3/16" diameter Stoody 6 at $4.25 per lb. will prove the merits of this alloy for any applications involving heat, corrosion, abrasion and impact. Available on AA-4 or higher priority rating.

STOODY COMPANY
1142 West Slauson Ave., Whittier, Calif.

STOODY HARD-FACING ALLOYS
Stop wear . . . Eliminate Repair

Appoints New Distributor

The National Supply Company announces the appointment of Houston Oil Field Material Company, Inc., of Houston, Texas, as distributor of National and Ideal oil field machinery and equipment. It has been a distributor of Spang pipe, another National product, since 1932.

Houston Oil Field Material Company, Inc., was organized in 1928 by virtually the present management for the purpose of distributing oil field specialties and to operate a cutting and fishing tool service. In the last 15 years it has expanded to a full line supply company catering to all the needs of the oil industry. The cutting and fishing tool service and its mud and chemical sales and service departments occupy a 5-acre site in Houston.

Homco operates 40 contact points and serves the Gulf Coast and other sections of the Mid-Continent area from Mississippi to the Mexican border. For the last 18 months the company has been actively engaged in war work, having prime contracts to build airplane landing gear struts for the United States Army Air Forces.

New L.A. Officers of A.P.I.

The following new officers have been elected by the Los Angeles Basin Chapter of the American Petroleum Institute: Chairman, W. J. Larson; vice chairman, Lloyd Metzner; secretary-treasurer, Dave M. Anderson, and assistant secretary-treasurer, Knight Templeton.

The retiring officers who will become members of the advisory board for the term ending 1945 are: Fred P. Miller, Robert P. Phillips, and Earle M. Boggess.

Elected Director

The Wickwire Spencer Steel Company announces the election of Samuel D. Lunt as a member of the board of directors replacing Charles G. Terry.

Lunt is the managing partner of the firm of Hamlin and Lunt, Buffalo, New York, stock brokers, members of the New York Stock Exchange.

New Atlanta Offices

New offices of Pittsburgh Equitable Meter Company-Merco Nordstrom Valve Company have been opened in Atlanta, Georgia. C. C. Moore, who has been in charge of the Memphis office, is district manager. The offices are at 411 Bona Allen Building, Spring and Luckie streets. The Memphis office was closed at the end of December, so that all southern operations formerly cleared through Memphis will now be handled through Atlanta.

ECOLITE 92BM
WITH LOCKING DEVICE AND SEALS

TWICE APPROVED for DOUBLE SAFETY
APPROVED BY
U. S. BUREAU OF MINES
UNDERWRITERS' LABORATORIES

—for use in atmospheres containing Methane or natural gas, gasoline or petroleum vapors. This double-safety lantern has a tamper-proof reflector and cover with locking device and seals. Throws 1500 ft. beam. Instantly ejects broken bulbs from battery circuit. Large handle—360° pivoting feature gives direct illumination where needed and leaves both hands free for work.

Now at Supply Stores

ECONOMY ELECTRIC LANTERN CO.
3100 W. CHERRY ST. MILWAUKEE 8, WIS.

For Boilers and Tubes
SAND-BANUM STANDARD

"The Entirely Different Boiler and Engine Treatment"

Automatically removes and prevents scale and corrosion in absolute safety to equipment and personnel while your equipment operates.

And—for DIESELS it's
BLUE SEAL EMULSION SAND-BANUM

Write Today FOR DATA

AMERICAN SAND-BANUM COMPANY, Inc.
9 Rockefeller Plaza, New York City 20

Stocks carried by
WESTERN SAND-BANUM COMPANY
Houston, Texas Fresno, California
and at other convenient points, including leading supply houses

Export Representatives
PETROLEUM MACHINERY CORP.
30 Rockefeller Plaza New York City 20

Howell Fills New Post

Benjamin F. Fairless, president of United States Steel Corporation of Delaware, has announced the appointment of M. D. Howell to the position of assistant to the president, a newly created post. The appointment of Howell, who will continue as vice president, secretary and treasurer of the Delaware corporation in addition to his new duties, became effective January 1, 1944.

Howell previously coordinated the activities of the corporation relating to government finance facilities, amortization, renegotiation, and termination of war contracts and production planning, and in his new position will be assigned additional special duties by the president.

Howell was formerly vice president of Carnegie-Illinois Corporation, prior to which he was a vice president of the Chemical Bank and Trust Company of New York.

Hays Promoted

G. K. Hayes, who has represented the John A. Roebling's Sons Company, manufacturers of wire rope and wire, Trenton, New Jersey, as a salesman out of the company's Cleveland branch for several years, has been appointed assistant manager of that branch.

G. K. HAYES

Hayes is a graduate of the University of West Virginia and has been connected with the company since 1930.

Link-Belt Elects

W. C. Carter, president of Link-Belt Company, Chicago, Illinois, announces the election by the board of directors, of two vice presidents, effective January 1.

E. L. Berry, vice president and general manager of Link-Belt Ordnance Company, has been elected vice president of Link-Belt Company, the parent organization. His new headquarters will be at the company's general office, 307 North Michigan Avenue, Chicago.

Richard F. Bergmann, company chief engineer, has been elected a vice president of Link-Belt Company, with headquarters at the company's general office, Chicago, as heretofore.

John E. Martin has been appointed manager of Link-Belt Ordnance Company, with headquarters at the plant.

AMERCOAT thermoplastic coatings *protect* structural materials of metal, wood and concrete from corrosion by acids, alkalies, chemicals, fumes, damp sea air, water, and other corrosive agents.

Amercoat also *protects* from contamination by the products of corrosion, many vital war and food supplies, such as aviation gasoline, diesel oil, chemical compounds, foods and beverages.

This *dual* protection against corrosion and contamination provided by Amercoat *conserves* critical materials and essential supplies.

Amercoat is used on structural steel, floors, walls, filters, tanks, tank cars, machinery, ship boottopping, laboratory equipment, sewage disposal plants, shower bases, laundry tubs, containers of many types and sizes . . . wherever equipment and buildings are exposed to corrosion, and products and supplies to contamination. New uses for Amercoat are being uncovered continually.

If you have a corrosion or contamination problem, find out whether Amercoat is the answer by writing for illustrated booklet which describes Amercoat and its many uses.

Amercoat thermoplastic coatings are applied cold—easily and quickly by spray or brush. Amercoat is odorless, tasteless, chemically inert. It is dielectric and possesses low water absorption. The coating adheres tightly . . . is hard, tough and impenetrable—yet flexible enough to withstand vibration and moderate expansion or contraction without checking, cracking or breaking.

MEET SPECIFIC COATING NEEDS

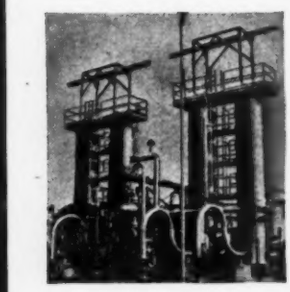
Amercoat compounds are modified, filled, pigmented or plasticized to meet the exact requirements of each particular coating job. Years of intensive research, tests and use in laboratory and field have gone into the development of Amercoat thermoplastic coatings.

PARTIAL LIST OF INDUSTRIES USING AMERCOAT

Chemical	Dairy
Petroleum	Hospital
Marine	Canning
Soap	Beverage
Shipbuilding	Transportation
Mining	Brewing, Distilling
Food	Laundry
Sewage Disposal	Cement
Construction	Fishing

Amercoat

Division of AMERICAN PIPE AND CONSTRUCTION COMPANY
P. O. BOX 3428, TERMINAL ANNEX • LOS ANGELES, CALIF.
Canadian Dist.: Gunite & Waterproofing, Ltd., Montreal, Quebec.



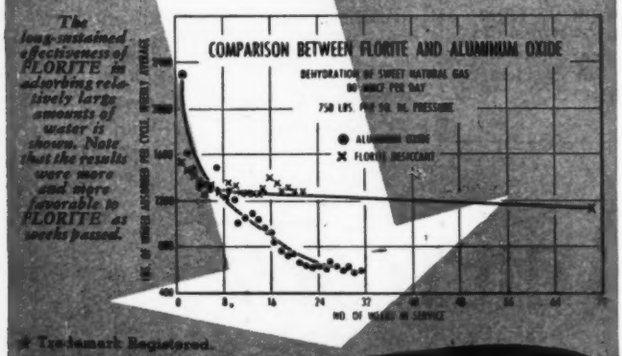
the Largest Operators use

Florite*

for dehydrating gas

In dehydrating natural gas — whether for pipe-line transmission and distribution, for repressuring, or for whatever purpose, FLORITE is likely to be found as the drying agent. Recent examples of approval have been noteworthy — names on request. Such demonstrations as the one represented below give the reason.

Long-term effectiveness, resulting in economy of operation, sums up the advantage. FLORITE selectively adsorbs 4 to 20% its weight of water, and is regenerated by heating to 350°F. Full details on request. Correspondence is invited.


COMPARISON BETWEEN FLORITE AND ALUMINUM OXIDE
DEHYDRATION OF SWEET NATURAL GAS
80 MMCF PER DAY
750 LBS. PER SQ. IN. PRESSURE
ALUMINUM OXIDE
FLORITE DESICCANT
LBS. OF WATER ADSORBED PER CYCLE, WEEKLY AVERAGE
NO. OF WEEKS IN SERVICE

The long-sustained effectiveness of FLORITE in adsorbing relatively large amounts of water is shown. Note that the results were more and more favorable to FLORITE as weeks passed.

* Trademark Registered.

FLORIDIN COMPANY, INC.

ADSORBENTS

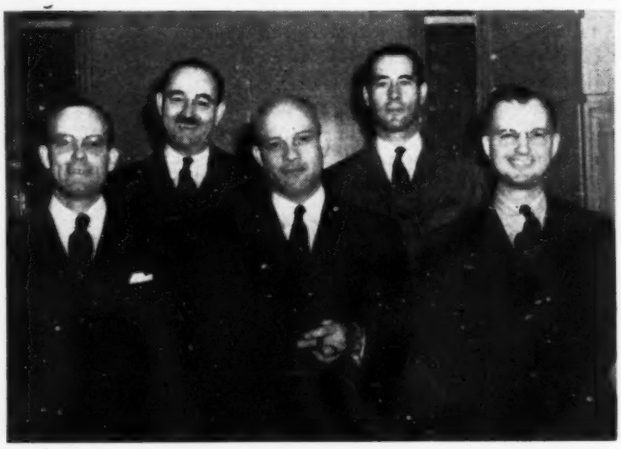
Room 54, 220 Liberty Street Warren, Pa.

W.P.R.A. Meeting

The board of directors of the Western Petroleum Refiners Association has selected St. Louis, Missouri, for the 32nd annual meeting. The sessions will be held at the Jefferson Hotel in that city on March 28, 1944, beginning at 10 a. m.

Due to congested hotel and railroad conditions, it is suggested that reservations be made far enough in advance to obtain suitable accommodations.

Dallas Engineers Elect Officers for 1944



Left to right: W. J. Jackson, J. W. Black, L. T. Potter, H. C. Laird, and C. G. Unlaub.

At a recent meeting of The Dallas Petroleum Engineers Club, L. T. Potter, vice president of the Lone Star Gas Company was elected president for the coming year. He succeeds Horace G. Saunders of the Cooper-Bessemer Corporation.

Other officers elected are: First vice president in charge of programs, W. J. Jackson, Lane-Wells Company; second vice president in charge of entertainment, H. C. Laird, Otis Pressure Control, Inc.; third vice president in charge of membership, C. G. Unlaub, C. G. Unlaub Company, and secretary-treasurer, J. W. Black, Magnolia Petroleum Company, re-elected for the second term.

The retiring officers, besides Saunders, are: First vice president, Charles B. Carpenter, U. S. Bureau of Mines, and third vice president, E. T. Eggers, American Steel and Wire Company.

The Dallas Petroleum Engineers Club just completed one of its most active and successful years. It now boasts a membership of 196, an increase of 150 over this time last year.

Sales Representative

The Bridgeport Brass Company, Bridgeport, Connecticut, has announced the appointment of The Bethlehem Supply Company as sales representative for Bridgeport condenser and heat exchanger tubing.

Emergency stocks of condenser tubes are maintained in some of the stores of the Bethlehem Supply Company, as well as at the warehouse of the Bridgeport Brass Company at Houston, Texas.

$1000 War Bond for Pump Name

Looking around for a trade name to identify all the pumps they manufacture, Fluid Pack Pump Company decided it was worth a $1000 war bond and agreed to give each of five others who made suggestions a $50 war bond for trying.

Every man in oil production and drilling at present and all those who are in the armed forces now but were previously in the same branches of the industry are eligible to win the $1000 bond or one of the five $50 bonds. Each man is allowed one entry and it must be mailed not later than March 15, 1944, to: Oil Well Pumps, 906 Bendix Building, Los Angeles 15, Cal.

Book Reviews

Empirical Equations and Nomography, by Dale S. Davis. Published by McGraw-Hill Book Company, New York, N. Y. Pages, 200.

Based on the theory that engineering data, in most cases, "cannot attain their maximum usefulness until they are connected by a reliable and practicable empirical equation," Dale S. Davis provides in this slim volume some of the methods to use in gaining careful correlation of specific data.

The book is in two parts, the first one dealing with the fundamental rectification methods thought to be most useful to the engineer. It also presents several new techniques for two-variable data, and places three-variable correlation on a firm basis. The second part is concerned with the theory and construction of alignment and line coordinate charts.

●

Maintenance Arc Welding, by 27 men in industry. Published by The James F. Lincoln Arc Welding Foundation, P. O. Box 5728, Cleveland, Ohio. Pages, 234. Price 50c in U. S., 75c elsewhere.

Written by recognized experts in various manufacturing fields, the 25 technical papers presented in this collection are fully illustrated with drawings and pictures to explain each step in the maintenance of items that require arc welding. The papers were selected as the most significant from a group that received awards at the 1940-42 Industrial Progress Award Program.

The volume will be found useful in keeping machinery and plants in operation despite critical shortages in materials and equipment. It is expected to have a tremendous influence in furthering the usefulness of the electric arc and in bringing about greater economies and benefits to industry as a whole.

●

Petroleum Reservoir Efficiency and Well Spacing, by the Committees on Reservoir Development and Operation of the Standard Oil Company (New Jersey) affiliated companies and of the Humble Oil and Refining Company. Published by the two companies. Pages, 77.

This volume contains the report of a four-year study of the behavior of petroleum in its original reservoirs far below the surface of the earth that has just been completed by engineers of the two oil companies. The survey correlates laboratory research carried on by the companies with actual field experience in both North and South America.

One of the most significant conclusions of the report is that the rate at which oil is withdrawn from its underground storehouse has an important bearing on the probable ultimate recovery from a particular field. Up to a certain point the greater the restriction on the rate of production the more thorough will be the recovery of oil from the sand, the Jersey-Humble survey concludes.

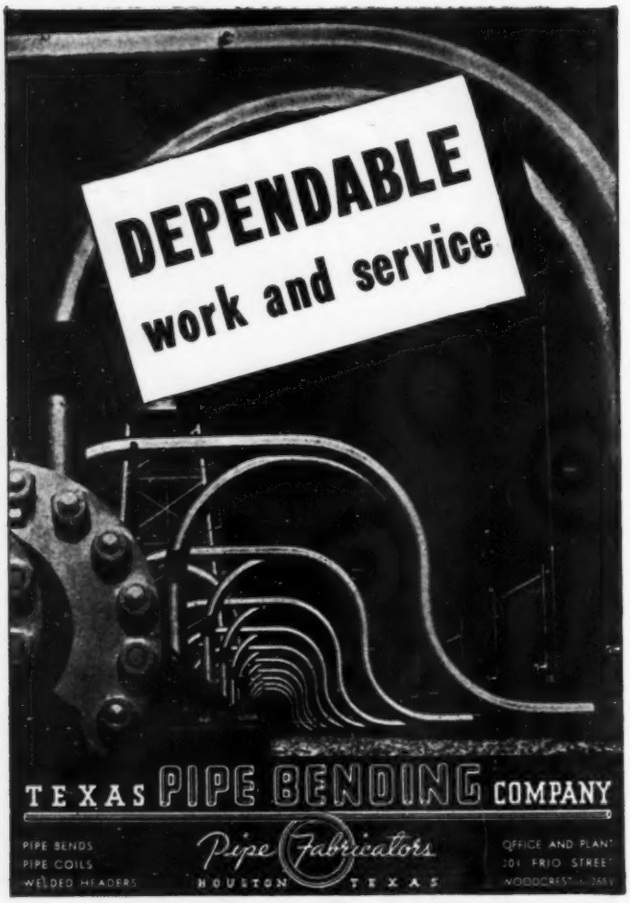
●

Encyclopedia of Substitutes and Synthetics, edited by Morris D. Schoengold. Published by Philosophical Library, Inc., 15 East 40th Street, New York, N. Y. Pages, 382. Price, $10.00.

This reference book, prepared with the cooperation of leading chemical and industrial laboratories in the United States, is the first of its kind in any language. It covers products that have been recently developed in order to replace critical materials that are difficult or impossible to obtain. In numerous instances such replacements as well as substitutes have proved superior to the original product.

Direct contact with the respective research laboratories by the editor supplied most of the information. Included are comprehensive explanations of plastics and other synthetics that for years have been replacing many applications of metal, as well as the late substitutes and synthetics.

ON GUARD
24 HOURS A DAY
GUIBERSON CATCHERS
PROTECT YOUR TUBING
Silently but nonetheless positively, the GUIBERSON TUBING CATCHER stands guard over your tubing—an unfailing safeguard against falling due either to overloading, faulty threads or any other cause. Its effectiveness has been demonstrated through years of successful use on thousands of wells . . . In peace, such inexpensive, permanent insurance is important; in war, it is imperative because it helps to conserve highly critical materials. See your Composite Catalog, or write
THE GUIBERSON CORPORATION
DALLAS, TEXAS
Expert Representative: I. FRANK BROWN
30 Rockefeller, Plaza, New York City
Calif. Distributor: W. R. GUIBERSON CO.
723 East Gage Ave., Los Angeles, Calif.
Now supplying critical materials to the Army, Navy, Marines and Army Air Forces
GUIBERSON
LIFE EXTENSION SERVICE FOR OIL WELLS



Machines for Making Money

At every step for 25 years we have asked ourselves one question: How can we make this pumping equipment save more money or make more money for our customers?

Unless JENSEN Pumping Units will save more money or make more money for YOU, we don't want or deserve your business. With that understanding, will you investigate? Turn to our pages in the new Composite Catalog or write us now for Bulletin No. 27. We think you'll be glad you did.

JENSEN
BROTHERS MFG. CO.
Coffeyville, Kansas, U. S. A.
Export Office: 50 CHURCH STREET, NEW YORK CITY

TRADE LITERATURE
What to Write For

"TIME PROVEN METHODS FOR THE REMOVAL OF PARAFFIN DEPOSITS," is a new and instructive handbook just off the press. It gives a total of 26 answers to the paraffin problem, presenting the most successful solvent application methods that chemical science has devised. Copies may be obtained from Dowell agents or from Dowell Incorporated, Kennedy Building, Tulsa 3, Oklahoma.

THE NEW 32-PAGE CRANE MANUAL, "Piping Pointers," takes up in detail the various types of valves and fittings and explains how to choose the most practical equipment for each use. This complete and informative piping booklet is available upon request to Crane Company, 836 South Michigan Avenue, Chicago 5, Illinois. A sound movie by the same name will be scheduled for showing without charge in any plant that arranges for it.

A VALUABLE REFERENCE BOOK for refinery engineers has been published by The Babcock and Wilcox Tube Company, Beaver Falls, Pennsylvania, which will send copies upon request. Technical Bulletin 6-D was prepared after intensive research and study of refinery problems on the subject of steel and alloy tubing. Its 157 pages are full of technical data, some never before published.

"WE WERE THERE" is the title of a book of tales about adventures in the war. The story of men and tanks and planes, it tells, too, of the drums of oil and gasoline that have gone with them to distant lands. Profusely illustrated with the portraits of world leaders and famous military men, the edition is beautifully bound. A copy will be sent free upon request to American Flange and Manufacturing Company, Inc., 30 Rockefeller Plaza, New York 20, New York.

WALL-COLMONOY CORPORATION, 720 Fisher Building, Detroit 2, Michigan, has just published its catalog No. 75 dealing with Colmonoy hard facing alloys and overlay metals. illustrations and detailed descriptions of available stock are included. A request will bring your copy.

A COMPREHENSIVE STUDY of industrial applications of National and Karbate carbon and graphite products has been published by National Carbon Company, P. O. Box 6087, Cleveland 1, Ohio, which will send a copy upon request. Physical characteristics, chemical resistance and standard sizes of various products are given in tables, and graphs supply performance curves of Karbate pumps.

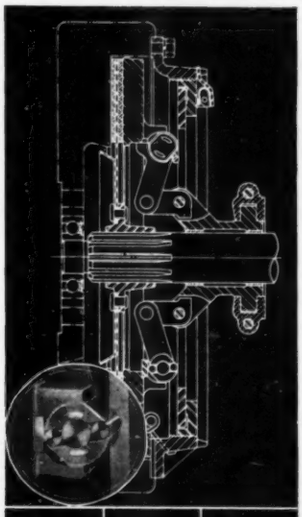
R-S BUTTERFLY PRECISION machined, wedge type valves are the subject of a 36-page catalog that is profusely illustrated with both manual and power operated valves for pressures from 15 to 900 lb. per sq. in. It contains detailed specifications, applications, and descriptions of new type valves. Write R-S Products Corporation, Wayne Junction, Philadelphia 44, Pennsylvania, for a copy of Catalog 14-B.

THE LATEST CATALOG OF SPERRY-SUN WELL SURVEYING COMPANY, 1608 Walnut Street, Philadelphia, Pennsylvania, is off the press and copies are available. It gives complete information of Sperry-Sun well surveying instruments and technical services.

THE WIRE ROPE CONSERVATION BULLETINS published by Macwhyte Company, Kenosha, Wisconsin, are now available in pamphlet form. It contains 22 illustrated articles on wire rope conservation, giving much valuable information. Copies may be obtained by requesting pamphlet No. 43-85.

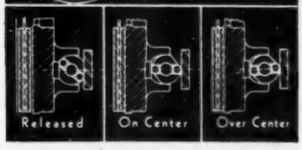
How ROCKFORD CLUTCHES Help Make Operation Extremely Easy

Anti-friction *ROLLER CAMS*—an exclusive feature—make ROCKFORD Over Center CLUTCH operation extremely easy. They exert heavy pressure evenly over the entire clutch face. Their smooth operation contributes substantially to long-time, reliable service — without adjustment. Hardened and ground rollers bear upon hard steel inserts in the pressure plate and upon the hardened adjusting ring plate. The cam shafts are forged steel, accurately machined and heat-treated for greater durability.

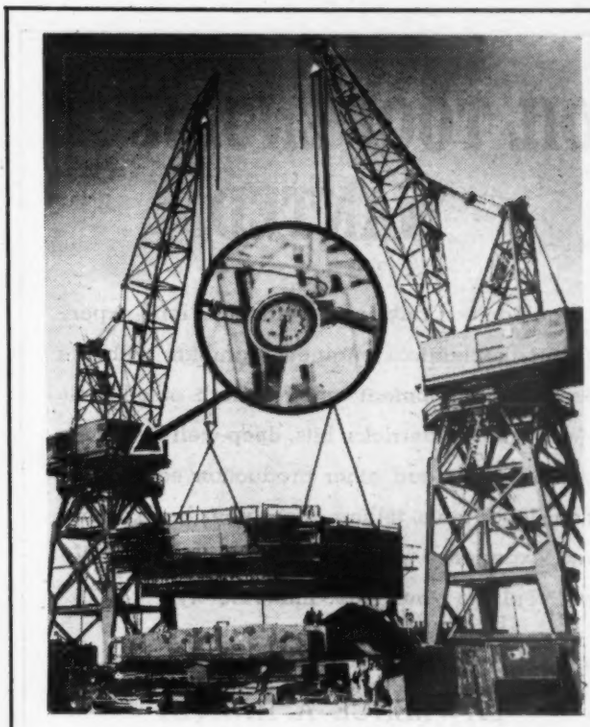


SEND FOR THESE HANDY BULLETINS ON POWER TRANSMISSION CONTROL

They tell and show how ROCKFORD CLUTCH and POWER TAKE-OFF applications are saving power, time and money in a wide variety of industries. Give capacities, dimensions and specifications.



Rockford Drilling Machine Division
Borg-Warner Corporation
1303 Eighteenth Ave., Rockford, Ill.



Whirley Cranes Equipped with Electric Line Scales and Electric Boom Radius Indicators

We'll be ready to serve our friends and customers in the oil industry, although a considerable amount of our present production is now going to the shipyards. Our original Line Scale design was for the oil industry, for the rugged uses of which it was made accurate, dependable. Your supply store has it—or will get it.

LINE SCALE CO., INC., Oklahoma City, Okla.

VICTOR MANUFACTURERS OF *Special*

BOLTS, STUDS, NUTS

of high strength, heat-treated alloy steels, corrosion and heat resistant alloys, non-ferrous metals and carbon steels for refineries, natural gasoline plants and manufacturers of refinery and oil field equipment.

also

VICTOR Heat-Treated alloy steel STUDS for flanged fittings and valves.

Write for complete Catalog!

VICTOR PRODUCTS CORP.
2643 Belmont Ave. Chicago, Ill.

ENSIGN CARBURETORS

Working for Victory

ENSIGN Carburetors for Natural Gas, Butane-Propane and Gasoline are playing an important part in the Victory effort. We are proud of this fact and are devoting our modern facilities and long experience to the successful completion of this assignment. Helping to win the war is our chief duty at this time.

But still available

ON THE HOME FRONT

However, ENSIGN Carburetors for Natural Gas, Butane-Propane and Gasoline are still available for uses not directly connected with the war effort. It may take us a little longer than usual to supply the demand for carburetors, but quick delivery of emergency parts is assured.

Now, as always, ENSIGN is unequaled for efficient and economical carburetion.

ENSIGN
CARBURETOR CO., LTD.
HUNTINGTON PARK • CALIFORNIA

Prepare, NOW, for post-war demands. Our competent engineering staff is at your service.

SUBSCRIPTION ORDER FORM

THE PETROLEUM ENGINEER,
Box 1589, Dallas, Texas.

(Enter) (Renew) my subscription for
1 year $2.00 ☐ 2 years $3.00 ☐

*Name*_____
*Company*_____
*Position*_____
*Home Address*_____
(or)
*Office Address*_____
*City*_____
*State*_____

OIL TOOL ENGINEER WANTED

Large Pacific Coast industry desires long-experienced mechanical engineer, familiar with the design, development and research of oil tools —particularly derricks, bits, deep-well hydraulic pumps, tongs and other production equipment. Your letter to us, telling about your background and experience, will be held confidential. We will reply to your letter immediately.

Please address:

LAWRENCE A. HARVEY

HARVEY MACHINE CO., INC.

6200 Avalon Blvd.

Los Angeles 1, California

SPERRY-SUN

COMPLETE INFORMATION

regarding Sperry-Sun Well Surveying instruments and technical services is given in our latest catalog. If you have not yet received a copy of this catalog, fill out the form below and we will gladly mail it to you.

Kindly mail me a copy of your latest catalog.

Name_____

Position_____

Company_____

Address_____

SPERRY-SUN WELL SURVEYING CO.

PHILADELPHIA, PA.

HOUSTON, TEXAS LONG BEACH, CALIF.

MEETINGS

California Natural Gasoline Association, Monthly Meeting—February 3, Rio Hondo Golf Club, Downey, California.

American Institute of Mining and Metallurgical Engineers, Annual Meeting—February 20, 21, 22, 23, and 24, Waldorf-Astoria, New York, New York.

American Society for Testing Materials, Spring Meeting—February 28-March 3, Netherland Plaza Hotel, Cincinnati, Ohio.

American Association of Petroleum Geologists, Society of Exploration Geophysicists, and Society of Economic Paleontologists and Mineralogists, Annual Meetings—March 22 and 23, Dallas, Texas.

Western Petroleum Refiners Association, Annual Meeting—March 28, Jefferson Hotel, St. Louis, Missouri.

American Association of Oilwell Drilling Contractors, 1944 Meeting—Fort Worth, Texas, date to be announced.

National Association of Corrosion Engineers—April 10, 11, and 12, 1944, Rice Hotel, Houston, Texas.

Natural Gasoline Association of America, Annual Meeting—April 13, 14, and 15, 1944, Baker Hotel, Dallas, Texas.

Petroleum Industry Electrical Association and the Petroleum Electric Supply Association—Last week in April, 1944, Dallas, Texas.

Southwestern Gas Measurement Short Course—June 6, 7, and 8, 1944, Norman, Oklahoma.

American Society for Testing Materials, Annual Meeting—June 26, 27, 28, 29, and 30, Waldorf-Astoria Hotel, New York, N. Y.

American Petroleum Institute, Annual Meeting—November 13, 14, 15, and 16, Stevens Hotel, Chicago, Illinois.

Gas Measurement Short Course in June

The Southwestern Gas Measurement Short Course, which has been held annually until last year, will be resumed in 1944. The motion to hold the course in 1944 was given a unanimous approval by the members of the general committee who attended the fall meeting at Dallas, Texas. The course will be conducted in the main building of the College of Engineering, on the campus of the University of Oklahoma, Norman, Oklahoma. The dates for the session are June 6, 7, and 8, 1944.

The omission of the course in 1943 was keenly felt by persons engaged in gas measurement and related work. This was especially true of new personnel who did not have an opportunity to receive the specialized training as given in an intensified form during the Southwestern Gas Measurement Short Course. Older employees also missed the schooling opportunities presented through this educational project.

The general committee instructed Earl Kightlinger, chairman of the program committee, to formulate a tentative program to be presented to the group at a meeting that will be held in Oklahoma City in January. It was suggested the morning sessions be devoted to elementary gas laws and the fundamentals of orifice meters, positive meters, and regulation. The afternoon sessions, as in past years, will deal with the fundamentals of regulation giving special attention to round table discussions and the opportunity for field men to receive help on any particular problems they might have.

Various manufacturers will be invited to have exhibits during the school, which will be used for the most part as visual aids to clarify material covered in lectures. Members of the armed services who are charged with the responsibility of gas measurement and distribution at their respective stations will be issued special invitations to attend the course this year.

Detailed announcements relative to this year's Southwestern Gas Measurement Short Course will be released early in March.